Injection-Molding Designers' Handbook

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ABSTRACT: This handbook summarizes design principles and guidelines to be applied when creating components molded of plastic materials. The information is presented to offer a manufacturing process perspective in the designing of plastic parts.

APPLICABILITY: This document applies to Digital engineers and designers who design features of or are involved in the manufacture of injection-molded thermoplastic parts.

STATUS: APPROVED 22-May-1991; use VTX SMC for current status.

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CHAPTER 1

INTRODUCTION

1.1 PURPOSE

This handbook summarizes design principles, guidelines, and information to be applied when creating components molded of plastic materials. These rules have been created so that engineers and designers can design Digital plastic parts with the manufacturing process in mind. By applying these rules, engineers and designers can design products that:

- are manufacturable, using standard manufacturing processes
- help provide designed-in quality
- lower the manufacturing cost through reduced cycle times, tooling costs, labor, and material
- lead to Six-Sigma compliance which requires the specification of the process width to be twice the process capability.

1.2 SCOPE

This handbook applies to features of injection-molded thermoplastic parts. The information is based on experiences with typical parts manufactured by Digital and the current Digital manufacturing capabilities. It is necessary to note that Digital's experience and the rules in this document apply to engineering thermoplastics, such as polycarbonate, but the rules are typically able to be generalized beyond these materials. It is not intended to identify all manufacturability problems; it identifies most common problems, and provides guidance along with the reasoning behind that guidance. It is not intended to overlap with the Finishing Rules Handbook. When more difficult or specialized problems occur, refer questions to a Producibility Engineer.

1.3 RESPONSIBILITIES

The Plastics Rules Group is responsible for the content of this handbook. Changes must be approved by the Plastics Rules Group prior to incorporation into this handbook. Send all comments and proposed changes to LEVERS::SANTANDREU. The team who created the initial issue of the handbook includes the following people.

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1.4 STRUCTURE OF DESIGN INFORMATION

This section describes the presentation format used in this handbook.

1.4.1 General Description

The plastics design information contained in this document takes the form of rules organized in a hierarchy of plastics design features and considerations. The hierarchy used to organize the rules provides a guide for users to locate appropriate information within this handbook. The text of the rules is uniformly formatted, and illustrations are included to aid in interpreting and using each rule.

1.4.2 Rule Format

The Plastics Design Rules in this handbook have been uniformly formatted as follows.

SECTION: Basic process classification to which each rule applies, for example "Injection Molding".

FEATURE: The feature or consideration about which each rule provides information, for example "Draft Angles".

RULE CATEGORY: Each rule falls under one of the following categories.

PRINCIPLE — a design rule that should not be broken.
GUIDELINE — a design rule which directs the user to the optimum solution.
INFORMATION — general knowledge, often dealing with hierarchy and information that applies to a large class of features.

RULE: The limitations, considerations, and other information specific to the feature at hand.

REASONING: The underlying fact or cause that provides the logic for the rule.

ALTERNATIVE: Provides a design choice outside the limits of the rule.

ALTERNATIVE IMPACT: The effect(s) of using the alternative rather than following the prescribed rule.

1.4.3 Structure of Design Handbook Information

This section puts injection-molding features information into the context of plastics design and manufacturing information.

1.4.3.1 Handbook Hierarchy

This handbook fits into the Molded Plastics volume of the Digital Design Handbook as follows.

Technology (Volume)	Molded Plastics
Process (Book)	Injection-Molded Thermoplastics
Specific Information (Chapter)	Design Features and Considerations
Feature Class (Section)	Projections, Depressions, and others

1.4.3.2 Organization of Injection-Molding Information

Figure 1–1 illustrates the *Plastic Design Rules Handbook* hierarchy. Figure 1–2 illustrates the organization of injection-molding features specific to this document and references the individual rules associated with each feature type.

Figure 1–1: *Plastic Designer's Handbook* Hierarchy Focusing on Injection-Molding Features

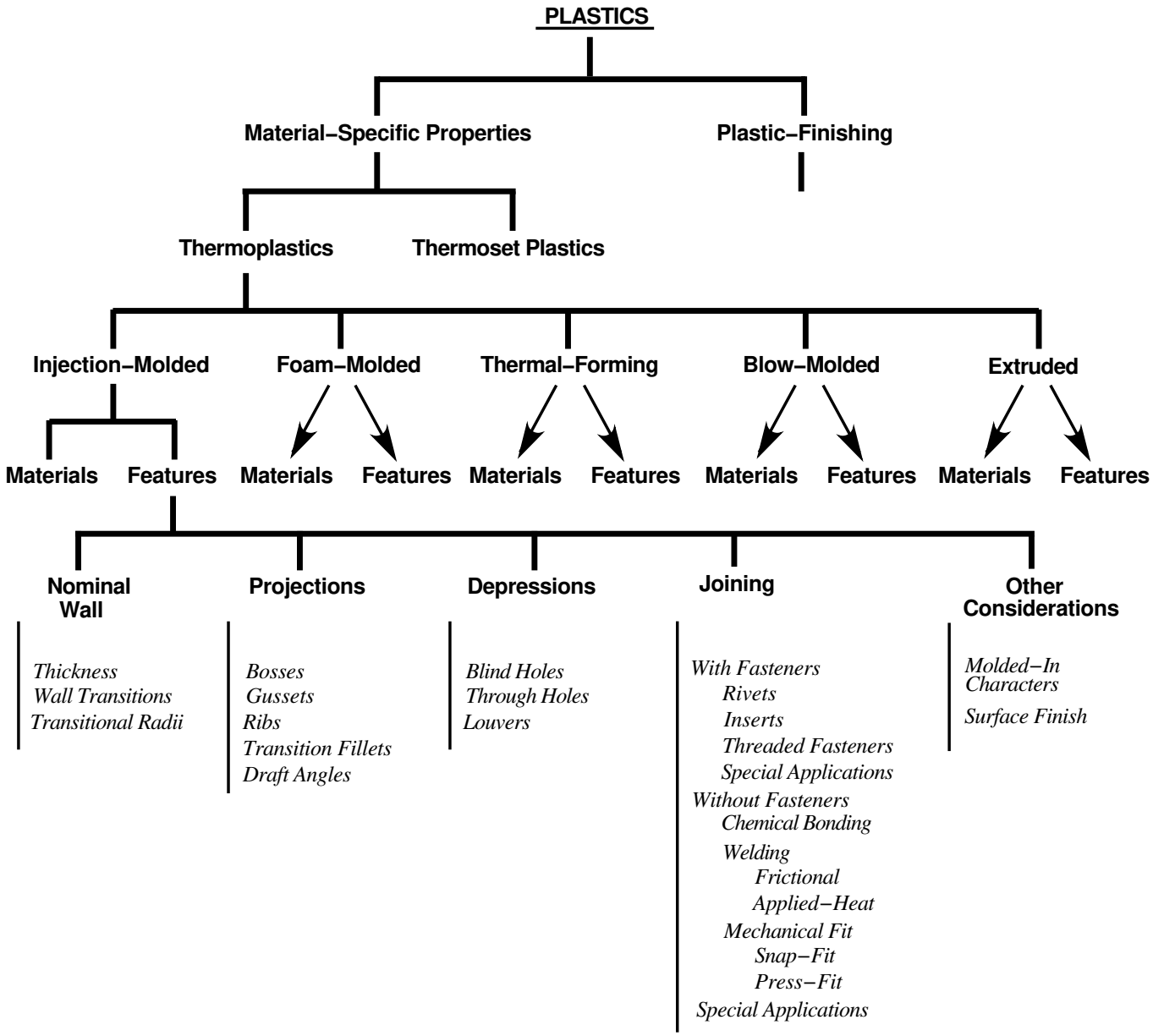

Figure 1–2: Injection-Molding Design Features Hierarchy and Associated Rules

2.1: Nominal Wall

Thickness (1.0)
Wall Transitions (1.1)
Transitional Radii (1.2)

2.2: Projections

Ribs (2.1)
Gussets (2.1.3)
Bosses (2.2)
Draft Angles (2.3)
Transition Fillets (2.4)

2.3: Depressions

Holes (3.1)
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Threaded Fasteners (4.3)
Machine Screws and Nuts (4.3.1)
Self–Threaded Screws (4.3.2)
Molded–In Threads (4.3.3)

2.4: Joining (continued)

Without Fasteners (4.4, .5, .6, .7)
Chemical Bonding (4.4)
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Spin–Weld (4.5.2)
Vibration (4.5.3)
Applied–Heat (4.6)
Hot–Plate (4.6.1)
Induction (4.6.2)
Bead (4.6.3)
Stake/Swage (4.6.4)
Mechanical Fit (4.7)
Snap–Fit (4.7.1)
Press–Fit (4.7.2)
Special Applications (4.8)

2.5: Other Considerations

Molded–In Characters (5.1)
Surface Finish (5.2)
(See also EL–EN729–01, "Finishing Rules Handbook for Plastics".)
(See also material data .)

CHAPTER 2

INJECTION-MOLDING FEATURES

FEATURE OVERVIEW

INFORMATION

RULE:

- Features within the plastic injection molding process can be divided into the following types:
    a. Nominal wall
    b. Projections
    c. Depressions
    d. Special features (such as hinges or snaps)
- Other dependent design considerations are:
    a. Material
    b. Finishing
    c. Joining

REASONING:
These major feature types should support all plastic injection molding design requirements and will support future automated design advisor development.

ALTERNATIVE:
Not applicable.

ALTERNATIVE IMPACT:
Not applicable.

2.1 UNIFORM WALL THICKNESS

PRINCIPLE

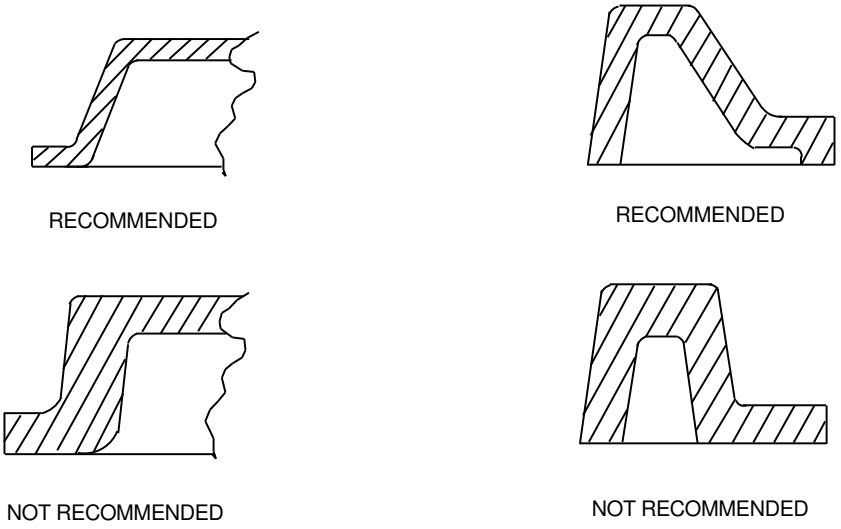
RULE:
PRIMARY PLASTIC RULE - Maintain uniform wall thickness.

REASONING:
Attention to detail must be exercised to avoid inadvertent heavy sections. Non-uniform wall thickness can cause sink marks, voids and non-uniform shrinkage. This can lead to dimensional problems, warpage and built-in stresses. Non-uniform wall thickness can also cause mold filling and cooling problems.

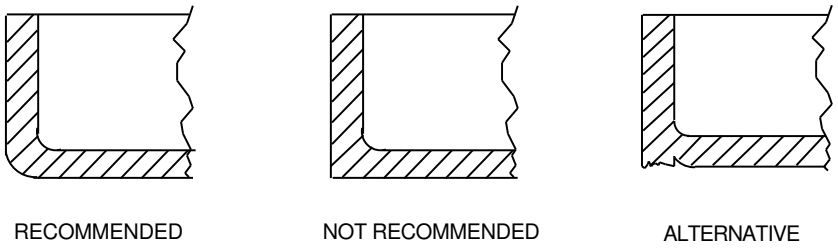
ALTERNATIVE:
If different wall thicknesses cannot be avoided, then the impacts can be reduced by creating a transition between thicknesses, coring out the thick section, or using a different design/manufacturing method. Thickness variation should not exceed 25%.

ALTERNATIVE IMPACT:
The above alternatives usually result in increased tooling and/or manufacturing costs.

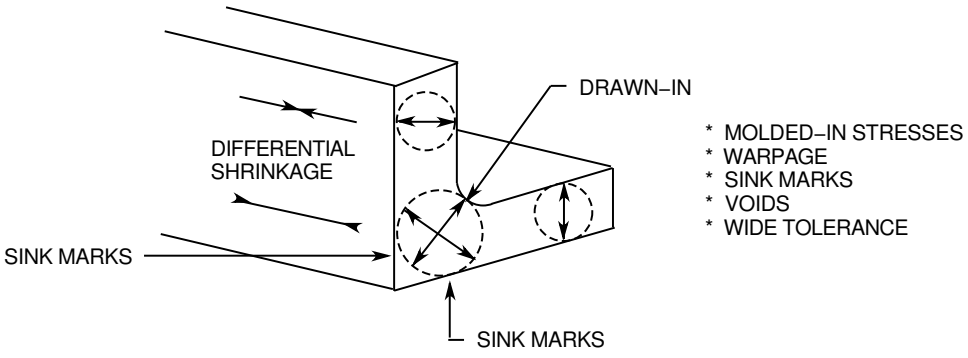
Figure 2–1: Uniform Wall Thickness



A: Cored Sections



B: Uniform Wall Designs



C: Effects of Nonuniform Wall Thickness

2.1.1 Transition - Wall Thicknesses

GUIDELINE

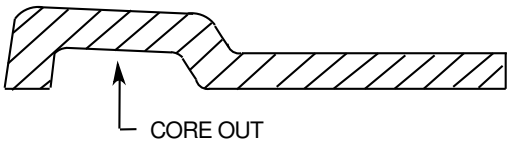
RULE:
Where different wall thicknesses cannot be avoided, a gradual transition between one thickness and the other should be included. The length of the transition should be at least three times the change in thickness, and the thickness variation should not exceed 25%.

REASONING:
Since abrupt changes in thickness increase the stress and can cause sink marks, voids and non-uniform shrinkage, a gradual transition from one thickness to the other should be used.

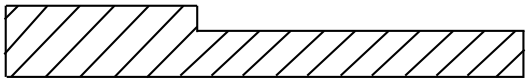
ALTERNATIVE:
Use ribs and gussets in place of the thicker section, insert separate parts, or use a different design/manufacturing method.

ALTERNATIVE IMPACT:
The above alternatives usually result in increased tooling and/or manufacturing costs.

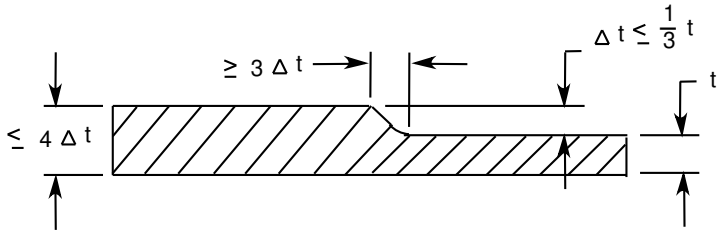
Figure 2–2: Transition - Wall Thicknesses



A: Recommended



B: Not Recommended



C: Alternative

2.1.2 Transitional Radii

GUIDELINE

RULE:
The inside corner radius (IR) should be a minimum of 1/4 of the Nominal Wall Thickness (NWT). The outside radius should be equal to the IR plus the NWT.

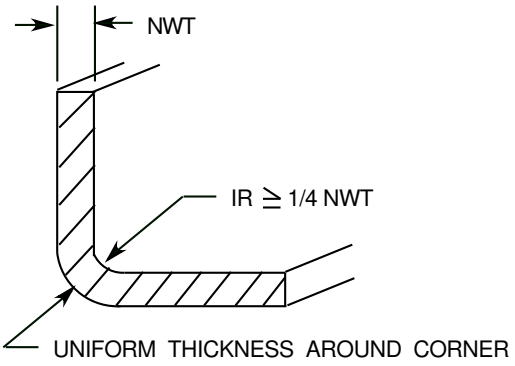
REASONING:
The surfaces of all intersections should be rounded. Large radii should be positioned at a junction of two or more surfaces to insure proper material flow and relieve any possibility of stress concentrations. Any sharp corner that is subject to loading and twisting will tend to be weak and break. Corner radii should be a minimum of 1/4 of the part thickness.

In order to maintain a uniform wall thickness, the outside radius should be the inside radius plus the NWT. Square corners cause flow marks, sink marks, and internal stresses.

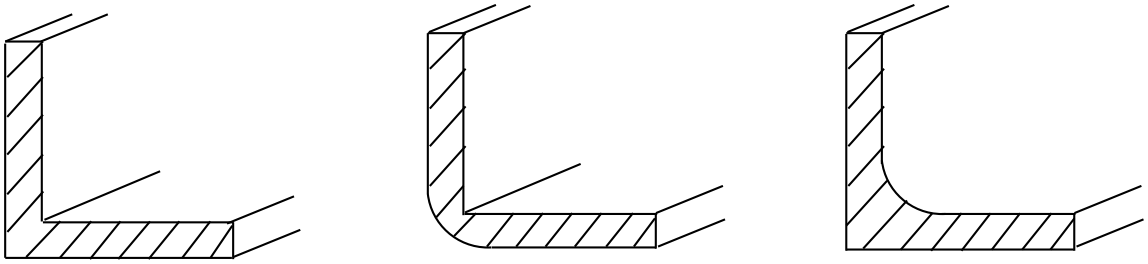
ALTERNATIVE:
Use largest radius possible.

ALTERNATIVE IMPACT:
The use of sharp corners usually increases mold and part costs and decreases quality.

Figure 2–3: Transitional Radii



A: Recommended Wall Transition Radii



B: Not Recommended Wall Transition Radii (or Lack of Radii)

2.2 PROJECTIONS

INFORMATION

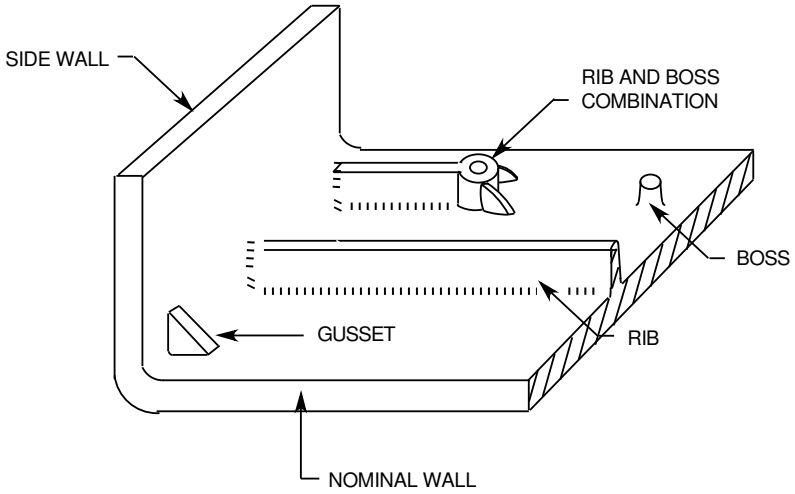
RULE:
Projections are plastic features that extend out from the nominal wall. They are generally classified as ribs, gussets and bosses. Projections can be combined, such as a gusset on a boss. Gussets are a special form of rib that form an angle between the nominal wall and the side wall or another projection.

REASONING:
The nominal wall is the start of the design of a plastic part. The side wall is usually considered an extension of the nominal wall. Ribs are projections used for strengthening, preventing warpage, and adding a function, such as directing the flow of air. They can be free-standing but it is recommended that they merge with the side wall or another projection for ease of mold filling and venting. Bosses are usually cylindrical projections, used for stand-offs and/or attaching other parts. Gussets are a special form of rib, used as support of the side wall or another projection. Projections can be combined to achieve the desired function, strength and quality. All projections should have a fillet or radius at the base to reduce stress and aid in mold design/use.

ALTERNATIVE:
The functions of projections can be performed by thicker walls and/or added parts.

ALTERNATIVE IMPACT:
The above alternatives usually result in increased cost and lower quality.

Figure 2–4: Projections



2.2.1 Ribs

GUIDELINE

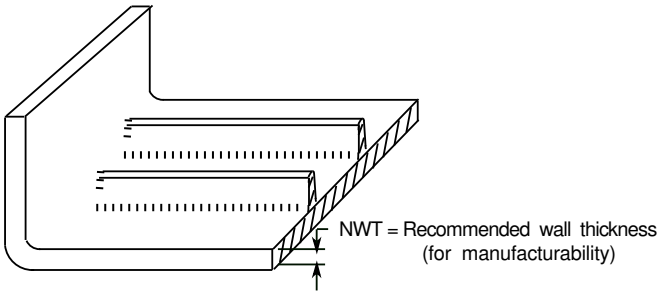
RULE:
Greater strength or stiffness is obtained by using ribs rather than increasing wall thickness.

REASONING:
Increased strength and stiffness can be obtained at less cost and weight by the correct use of ribs.

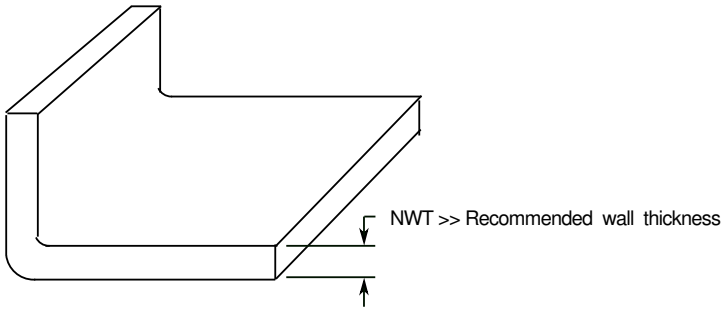
ALTERNATIVE:
Use thicker walls, a different material, different design/manufacturing method, and/or multi-part construction.

ALTERNATIVE IMPACT:
The above alternatives could result in increased costs and decreased quality (sink marks, warpage, internal stresses and dimensional problems).

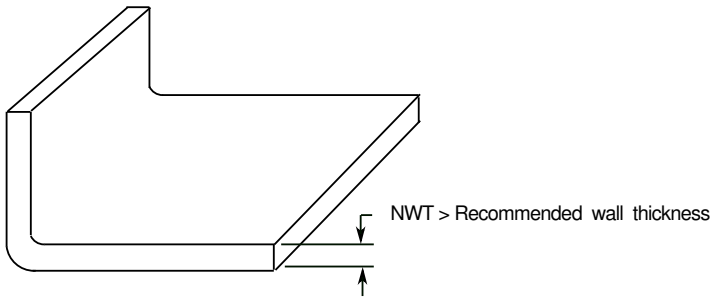
Figure 2–5: Ribs



A: Recommended: Ribs used to stiffen wall while reducing thickness.



B: Not Recommended: Thick walls used for improving stiffness.



C. Alternative: Use stiffer material to reduce thickness of a wall with or without ribs.

2.2.1.1 Rib Design

GUIDELINE

RULE:

- Rib width should be 50% to 65% (recommended 60%) of NWT. Rib height should not exceed 2.5 times rib width. Parallel ribs should be placed at least two rib widths apart.
- It is better to have two or more narrow ribs than one wide rib.

REASONING:
Ribs must be designed in the right proportions if they are to completely fill the mold, provide the correct strength, and not cause sink marks.

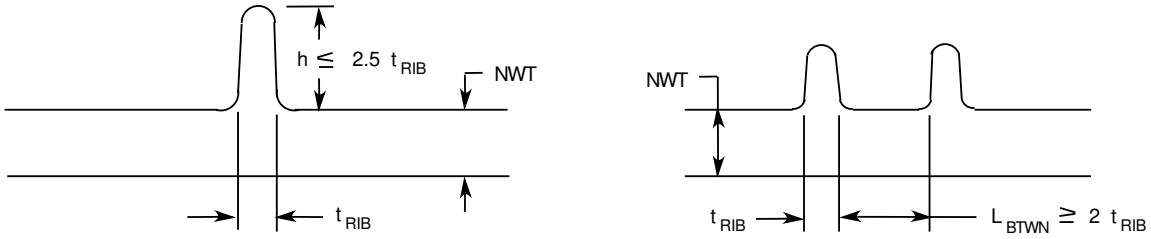
NOTE

For a significant number or a complex arrangement of ribs, refer to the Producibility Engineer.

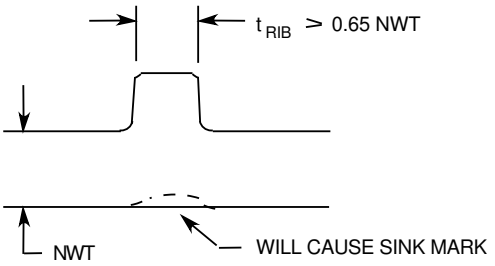
ALTERNATIVE:
Use thicker walls, different material, a different design/manufacturing method, and/or multi-part construction.

ALTERNATIVE IMPACT:
The above alternatives could result in increased costs and decreased quality (sink marks, warpage, internal stresses, and dimensional problems).

Figure 2–6: Number of Ribs



A: Two Recommended Designs



B: Not Recommended

2.2.1.2 Ribs and Venting

GUIDELINE

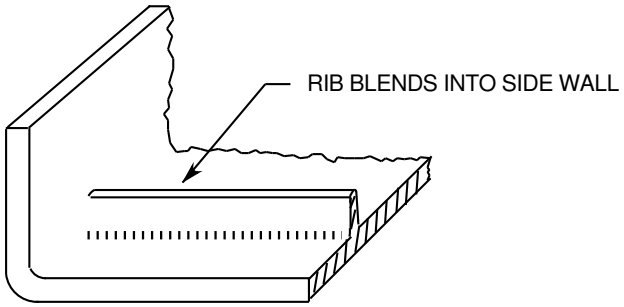
RULE:
Ribs should connect to a side wall or another projection.

REASONING:
It is preferable to have the rib join the wall or another projection for the easy removal of trapped gases.

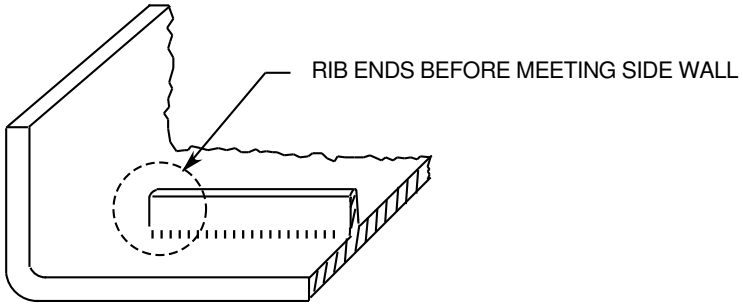
ALTERNATIVE:
If the rib is freestanding, filling will be made easier by adding intermittent heavy sections on which a vent pin can be placed in the mold to allow for venting.

ALTERNATIVE IMPACT:
The above alternative will result in increased mold cost.

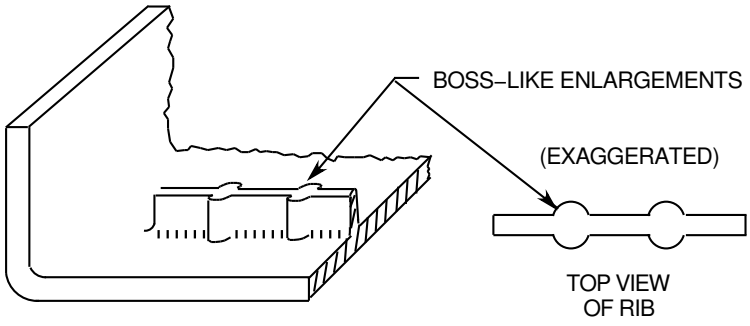
Figure 2–7: Ribs and Venting



A: Good practice: Rib end side wall



B: Freestanding rib is not preferred



C. Alternative practice: Freestanding rib has enlargements for ejector / vent pins

2.2.1.3 Gussets

GUIDELINE

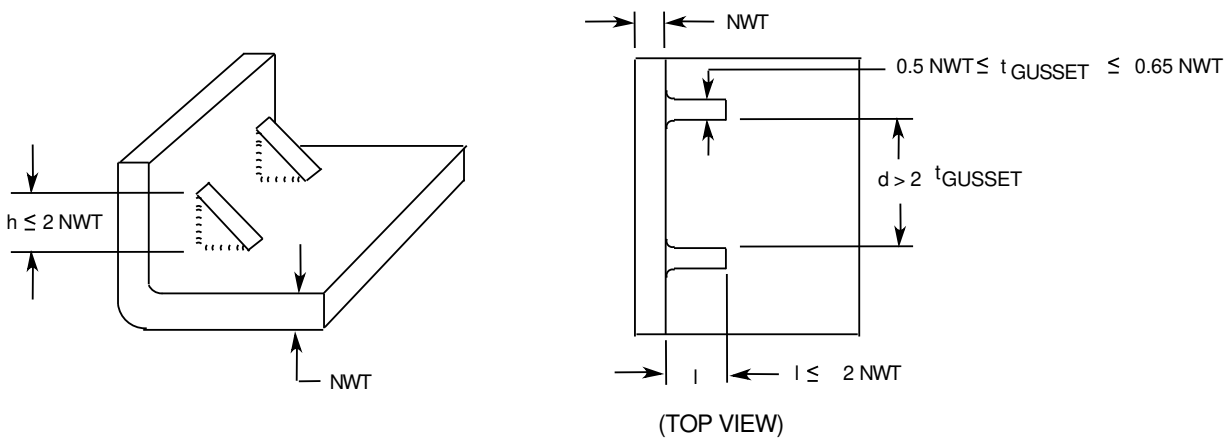
RULE:
Gussets are special forms of ribs supporting a wall and are based upon the NWT. They should be no longer than twice NWT, as wide as 50% to 65% (recommended 60%) NWT, and spaced at least two times gusset width. For additional support, two or more gussets do a better job than increasing the height or width of one.

REASONING:
Gussets are supporting features for a wall or projection.

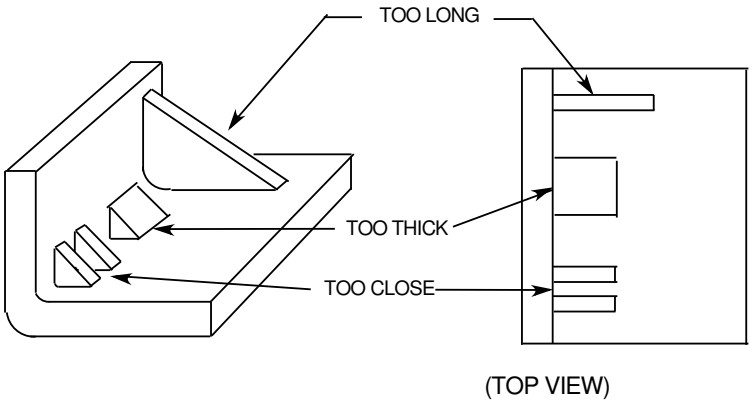
ALTERNATIVE:
Use thicker walls, different material, a different design/manufacturing method, and/or multi-part construction.

ALTERNATIVE IMPACT:
The above alternatives usually result in increased costs and decreased quality (sink marks, warpage, internal stresses and dimensional problems).

Figure 2–8: Gussets



A: Recommended Gusset Design



B: Not Recommended Gusset Designs

2.2.2 Bosses

This section contains rules specific to the design of bosses.

2.2.2.1 Hollow Bosses

GUIDELINE

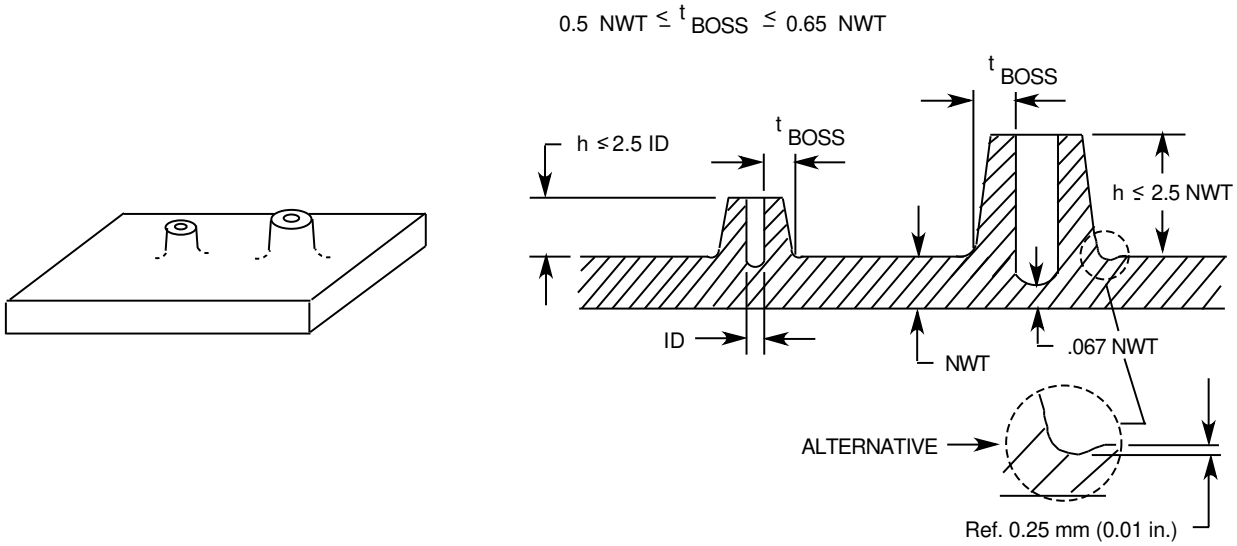
RULE:
The wall thickness of the boss should be 50% to 65% (recommended 60%) of the NWT. The height of the boss should not exceed 2.5 times the Inside Diameter (ID) of the boss or 2.5 NWT, whichever is less. Recess the core of the boss 33% into the nominal wall. Shapes other than round should be avoided.

REASONING:
Bosses are defined as projections that assist in assembly with other parts. Because they are frequently the anchoring member between the parts, they are subject to strains and stresses not found in other areas of the part. Recessing the core 33% into the nominal wall avoids sink marks. The designing of bosses with cross sections other than round should be avoided. Square or oval holes are difficult to machine into mold steel and result in a more expensive mold.

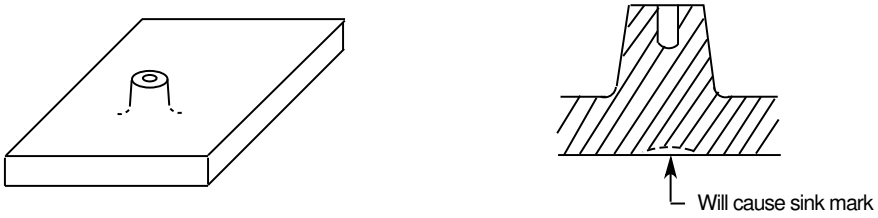
ALTERNATIVE:
Use different material, a different design/manufacturing method, and/or multi-part construction.

ALTERNATIVE IMPACT:
The above alternatives could result in increased tool, part, and process costs.

Figure 2–9: Hollow Bosses



A: Recommended Hollow Boss Design



B: Not Recommended Hollow Boss Design

2.2.2.2 Bosses With Ribs/Gussets

GUIDELINE

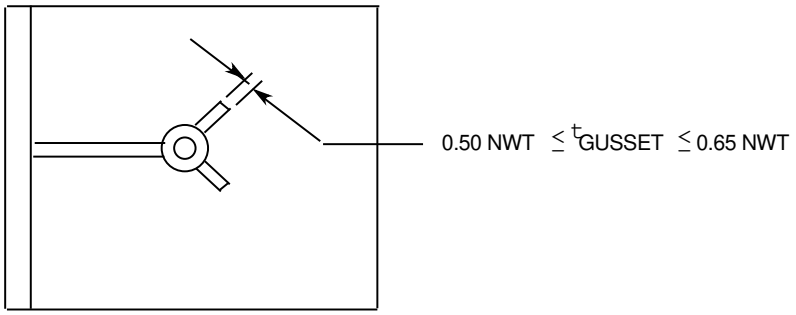
RULE:
The width of any rib/gusset attached to a boss should be 50% to 65% (recommended 60%) of the NWT. These ribs should be attached to the side wall, or should be in the form of gussets with a maximum height of 95% of the boss height.

REASONING:
Any attached member to the wall should not be thicker than 50% to 65% of the NWT or sink marks will likely occur.

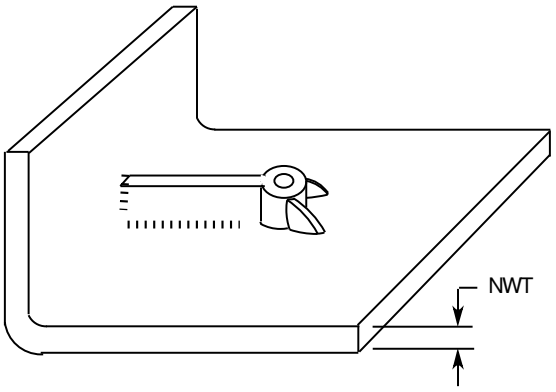
ALTERNATIVE:
Use a thicker nominal wall, different material, a different design/manufacturing method, and/or multi-part construction.

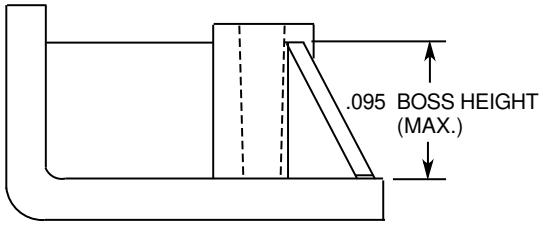
ALTERNATIVE IMPACT:
The above alternatives could result in increased costs and decreased quality (sink marks, warpage, internal stresses and dimensional problems).

Figure 2–10: Bosses with Ribs/Gussets



(TOP VIEW)





(SIDE VIEW)

2.2.3 Draft Angles

GUIDELINE

RULE:

- All projections, depressions, or side walls should have a draft angle to the draw of the mold with a minimum of one degree or more recommended.
- Surface texture requires additional draft of 1 degree per 0.025 mm (.001 inch) of texture depth.

NOTE

One degree = 0.017 mm/mm (0.017 in/in).

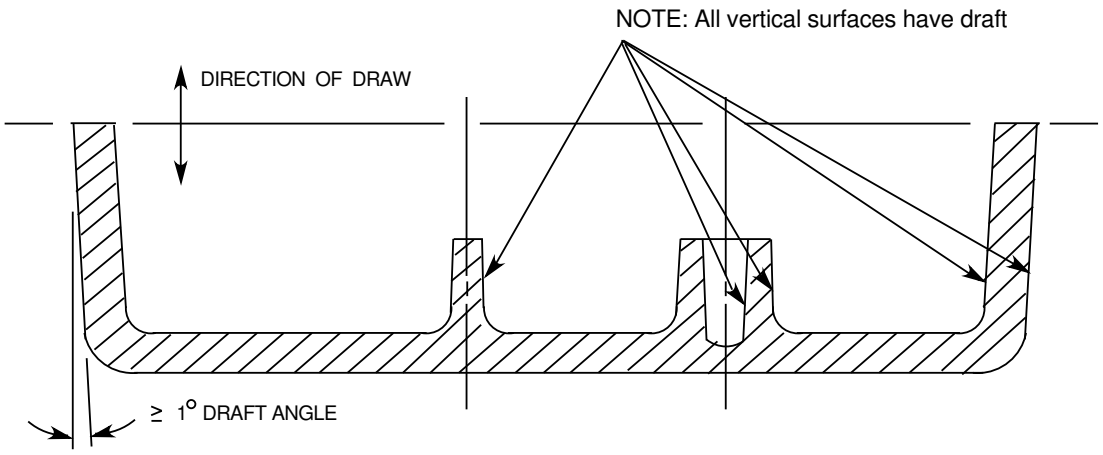
REASONING:
Proper draft angles to the draw of the mold are required on projections and depressions to facilitate removal of the part from the mold. Texturing depth increases the part/mold friction and requires greater angles.

Refer to the design rule on surface finishes and the Plastic Finishes Rules.

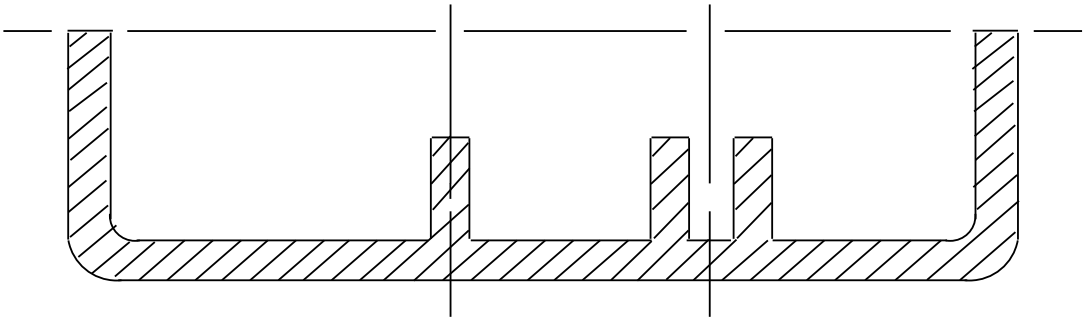
ALTERNATIVE:
Design the part with a smaller draft angle and use additional ejector pins, side action, and/or collapsing cores. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Special or additional mold features such as ejector pins, side action, and so forth, increase the cost and maintenance and decrease the life of a die. They may also mark the part with witness lines, possibly decreasing the quality of the part.

Figure 2–11: Draft Angles



A: Recommended



B: Not Recommended

2.2.4 Fillets

GUIDELINE

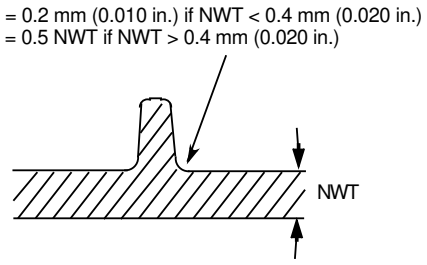
RULE:
Fillets of ribs and bosses should be a minimum of 0.2 mm (0.010 inch) radius or 50% of NWT, whichever is greater.

REASONING:
Fillets are used at the base of ribs or bosses to facilitate the flow of plastic material and to eliminate sharp corners, thus reducing stress concentrations in the molded part. The radius of these fillets should be at least 0.2 mm (0.010 inch). The addition of a fillet increases the life of the mold and the strength of the molded part. Optimum strength is obtained at 50% of NWT. Excessive fillets can cause sink marks. Refer to the Producibility Engineer.

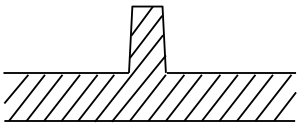
ALTERNATIVE:
Use sharp corners or recessed radii.

ALTERNATIVE IMPACT:
The use of sharp corners usually decreases the quality and strength of the part.

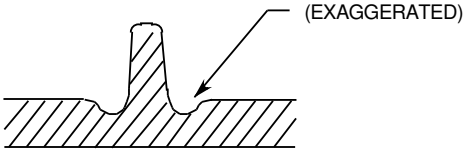
Figure 2–12: Fillets



A: Good practice: Rib end side wall



B: No fillets (zero radius) is not preferred



C: Alternative practice: recessed radii

2.3 DEPRESSIONS

INFORMATION

RULE:
Depressions are plastic features that extend into the nominal wall.

a. Those which penetrate the wall are called through holes, slots, louvers, and so forth.

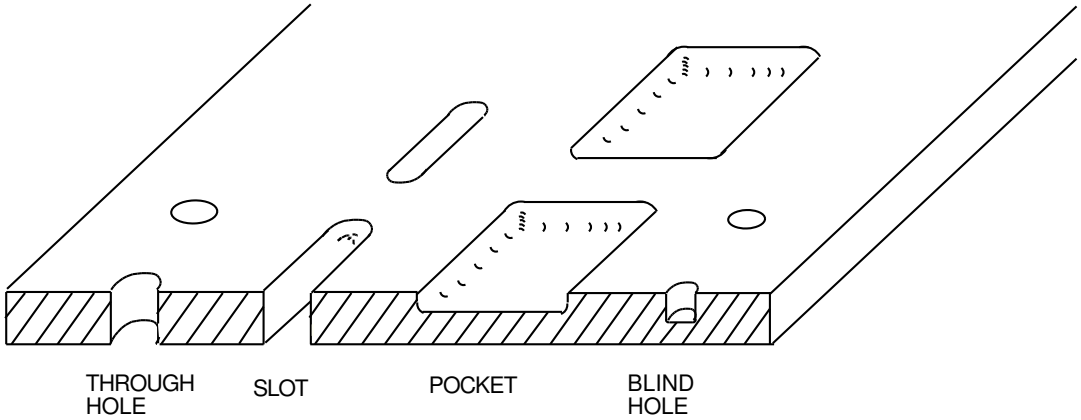
b. Those which penetrate only part-way through the wall are called blind holes and recessed pockets.

REASONING:
The nominal wall is the start of the design of a plastic part. Depressions are reductions of the nominal wall. Through holes and other depressions are often used for assembly, locating, clearance or cooling. Blind holes and pockets are often used for clearance or locating. Coring produces blind or through holes and is used to reduce the mass of material.

ALTERNATIVE:
Depressions could be formed by additional operations such as drilling and counter boring.

ALTERNATIVE IMPACT:
The above alternatives usually result in increased cost and reduction of quality.

Figure 2–13: Depressions



2.3.1 Holes - Classification

INFORMATION

RULE:
Holes are classified by:

a. Form factor: blind, through, or step.

b. Relation to the mold draw: parallel, perpendicular and oblique.

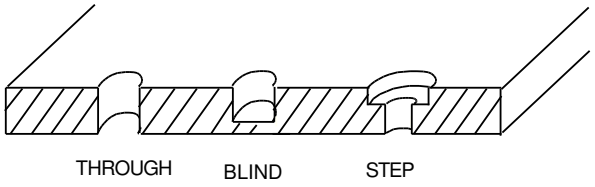
REASONING:
Molded holes are classified by form factor as blind, through or step.

In terms of mold draw relationship, a hole parallel to the draw is a hole whose axis is parallel to the movement of the mold as it opens and closes. Holes may also be molded at right angles (perpendicular) to the draw and at oblique angles. However, holes perpendicular to the mold draw require slides or retractable core pins, increasing mold costs and complexity. Oblique-angle holes should be avoided wherever possible. It is very difficult and expensive to make a mold that can operate at oblique angles, as they require split action molds and retractable core pins.

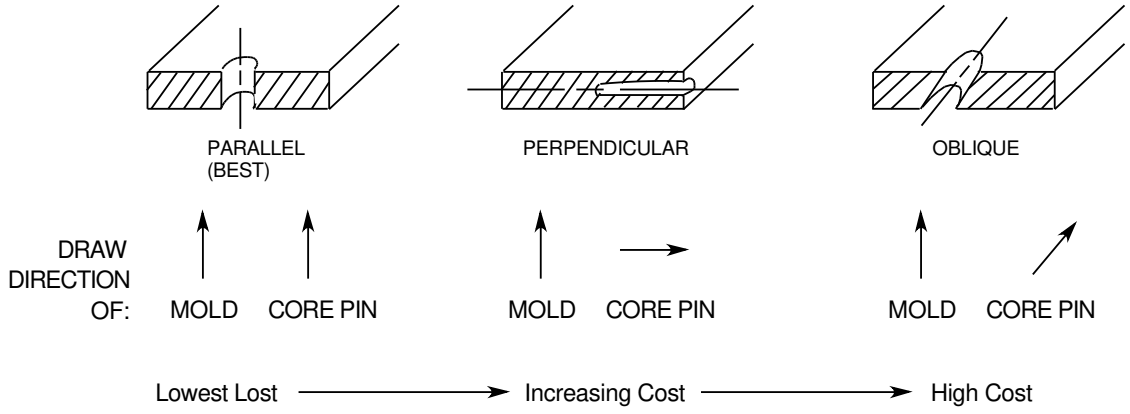
ALTERNATIVE:
Use a secondary operation such as drilling or routing.

ALTERNATIVE IMPACT:
Secondary operations increase the cost.

Figure 2–14: Holes - Classification



A: Hole Form Classification



B: Relation of Hole Draw Directions to Cost

2.3.1.1 Holes - Slenderness Ratio

GUIDELINE

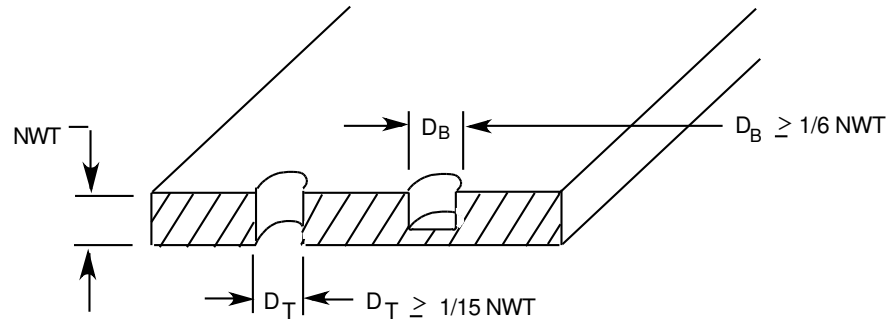
RULE:
The diameter of blind holes should be no less than 1/6 the NWT. The diameter of through holes should be no less than 1/15 the NWT.

REASONING:
Molded holes are formed by core pins. These core pins are subject to breakage and wear. The strength of the pin is influenced by the ratio of its mean diameter to its length, and is called its slenderness ratio. Through holes can be formed by pins from both sides. Deep holes may require stepped pins.

ALTERNATIVE:
Use secondary operations.

ALTERNATIVE IMPACT:
Secondary operations increase costs.

Figure 2–15: Holes - Slenderness Ratio



Recommended Minimum Hole Diameters

2.3.1.2 Holes - Nearness to Other Holes

GUIDELINE

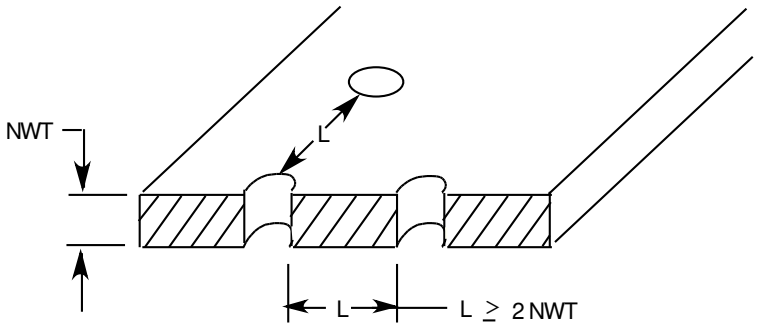
RULE:
The distance between two through holes should be a minimum of two times the NWT.

REASONING:
The flow of resin around a core pin and the joining of the resin on the other side of the pin cause weld lines, which are weak points. To insure part strength, the distance between through holes should be a minimum of two times the NWT.

ALTERNATIVE:
Combine holes to larger/elongated hole or use secondary operations.

ALTERNATIVE IMPACT:
Secondary operations increase costs. Refer to the Producibility Engineer for specific requirements.

Figure 2–16: Holes - Nearness to Other Holes



Recommended Hole Spacing

2.3.1.3 Holes - Nearness to Side Wall

GUIDELINE

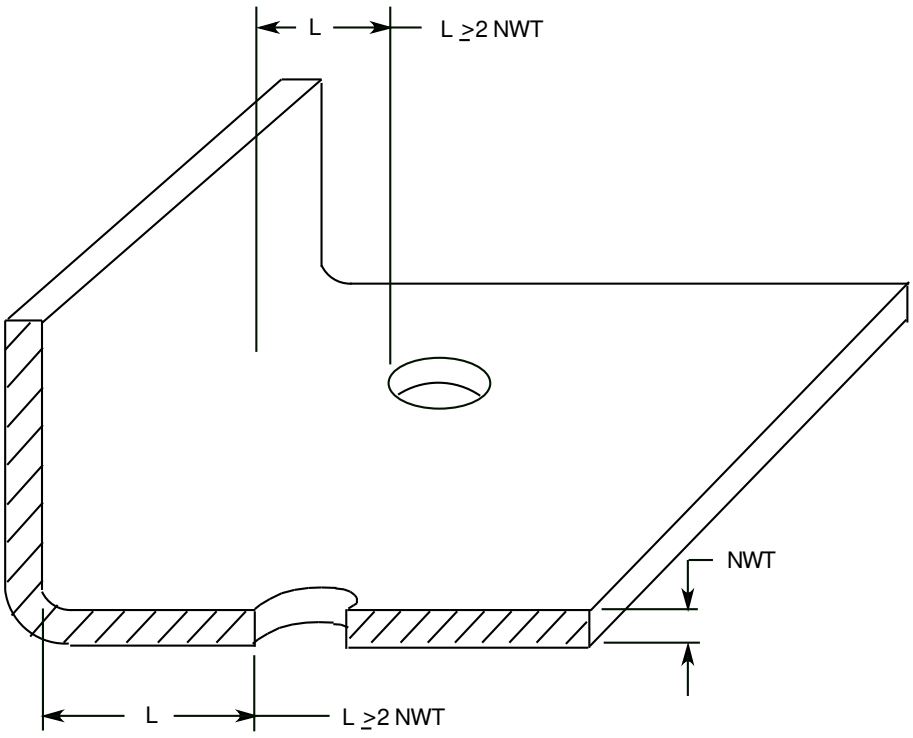
RULE:
The distance between a molded through hole and the side wall should be a minimum of two times the NWT.

REASONING:
The flow of resin around a core pin and the joining of the resin on the other side of the pin cause weld lines, which are weak points. To insure part strength, the distance between a molded hole and the side wall should be a minimum of two times the NWT.

ALTERNATIVE:
Holes can be closer, including into the side wall, provided special tooling action is taken. Refer to the Producibility Engineer.

ALTERNATIVE IMPACT:
Special tooling action increases the tooling cost.

Figure 2–17: Holes - Nearness to Side Wall



2.3.1.4 Holes - Nearness to Edge

GUIDELINE

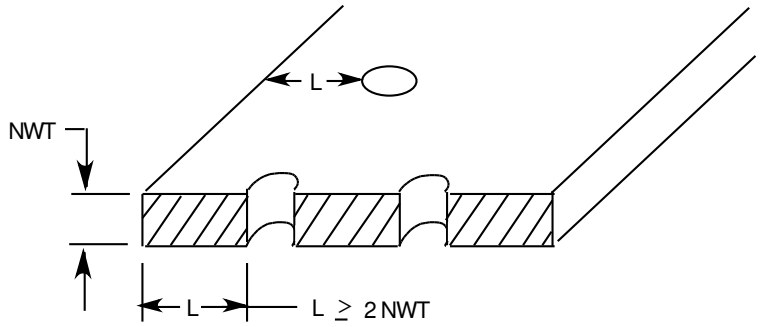
RULE:
The distance between a molded through hole and the edge of the part not at a side wall should be a minimum of two times the NWT.

REASONING:
The flow of resin around a core pin and the joining of the resin on the other side of the pin cause weld lines, which are weak points. To insure part strength, the distance between a through hole and the edge of the part not at a side wall should be a minimum of two times the NWT.

ALTERNATIVE:
The hole could be enlarged to form a notch in the edge, or a secondary operation could be done.

ALTERNATIVE IMPACT:
Secondary operations increase costs. Refer to the Producibility Engineer for specific requirements.

Figure 2–18: Holes - Nearness to Edge



Recommended Hole Distance from Edge

2.3.1.5 Holes - Blind Holes

GUIDELINE

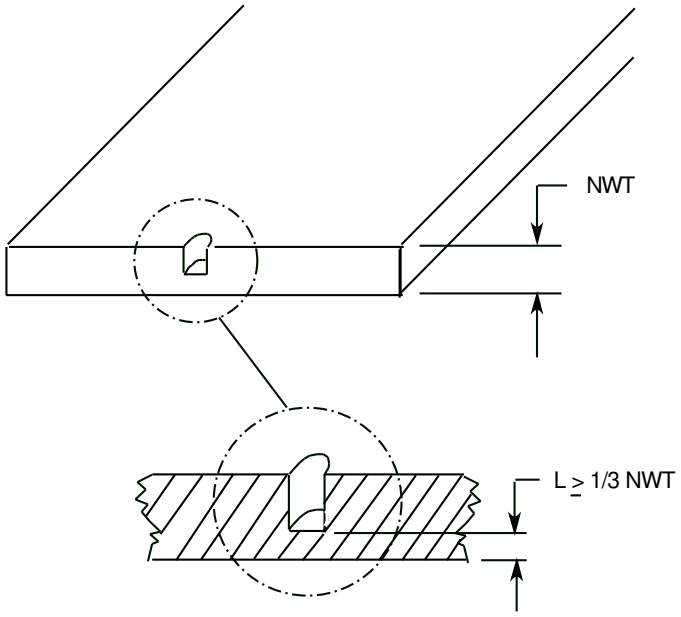
RULE:
The bottom wall thickness of a blind hole or recessed pocket should be at least 1/3 of the NWT.

REASONING:
If the wall at the bottom of a blind hole is less than 1/3 of NWT, a material void may occur at that location. See the Producibility Engineer for specific design recommendations.

ALTERNATIVE:
Add a protrusion opposite the feature to maintain NWT or drill the hole with a secondary operation.

ALTERNATIVE IMPACT:
A protrusion means a more costly tool. Secondary operations add cost to each part.

Figure 2–19: Holes - Blind Holes



Good Practice: Blind Hole Depth

2.3.2 Louvers

INFORMATION

RULE:
Louvers are features that extend through the nominal wall. They are usually a series of rectangular or oblong slots used to promote air flow for cooling purposes and can extend through two or more planes.

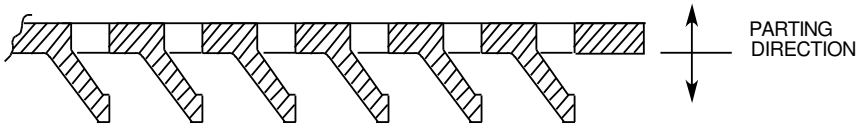
- Rules applying to through holes also apply to louvers.
- Special consideration must be given to the product's EMI/RFI, acoustic, thermal, and Industrial Design requirements.

REASONING:
The proper use of louvers results in a part that meets the product's cooling, EMI/RFI, acoustic, and appearance requirements.

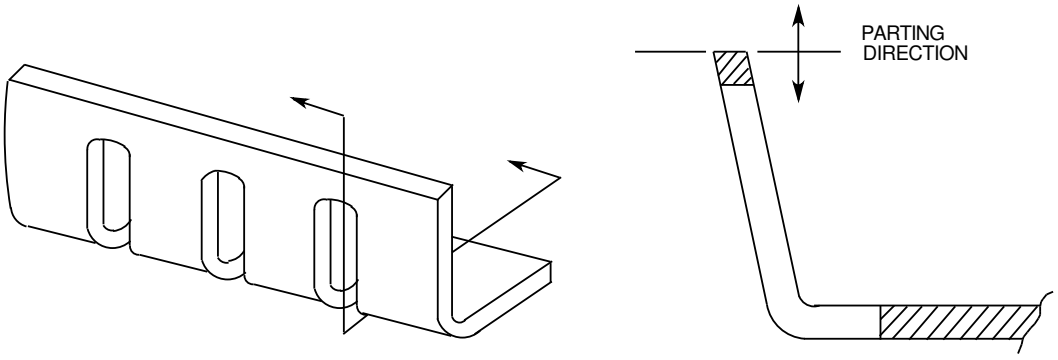
ALTERNATIVE:
Not applicable.

ALTERNATIVE IMPACT:
Not applicable.

Figure 2–20: Louvers



A: Cross section of blind louver pattern



B: Cross section of vertical side wall louver

2.4 FASTENING AND JOINING

INFORMATION

RULE:
Plastic parts can be joined to other parts by one or more of the following means.

I. With fasteners
- a. Rivets
- b. Inserts
- c. Thread fasteners
  1. Machine screws/nuts
  2. Self-threading screws
  3. Molded-in threads
- d. Special applications

II. Without fasteners
- a. Chemical bonding
  1. Adhesives
  2. Solvents
- b. Welding
  1. Frictional
     - Ultrasonic
     - Spin-weld
     - Vibration
  2. Applied-heat
     - Hot-plate
     - Induction
     - Stake
     - Bead
- c. Elastic displacement - snap fit
- d. Mechanical - press fit

REASONING:
These fastening methods should support all thermoplastic-injection molding assembly design requirements and will support future automated design advisor development.

ALTERNATIVE:
Not applicable.

ALTERNATIVE IMPACT:
Not applicable.

2.4.1 Rivets

GUIDELINE

RULE:

- Rivets are a means to permanently join metal and plastic parts in shear applications. They are not recommended for applications in tension.
- The distance of the rivet from any edge should be at least three times the shank diameter. The clinch allowance should be at least 0.6 times the shank diameter, with a washer recommended between the clinch and the plastic part.
- Blind rivets are not recommended for plastics.

REASONING:
Rivets are a permanent means of joining metal and plastic parts under shear. They cannot be disassembled without destroying the rivet and/or part.

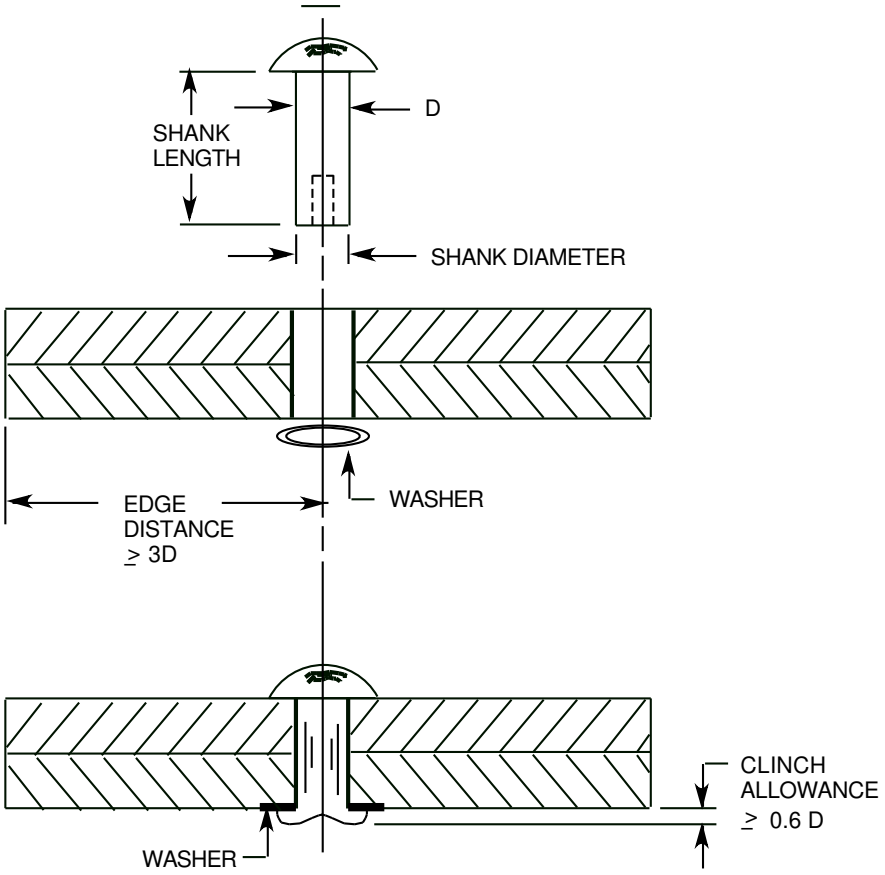
Care must be taken to assure that the area under the head and swage provides adequate bearing strength, with a washer being recommended in most applications.

Blind rivets may fracture the plastic.

ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to Producibility Engineer.

Figure 2–21: Rivets



Note: Edge distance ≥ 3 x shank diameter
Clinch allowance ≥ 0.6 x shank diameter

2.4.2 Inserts

INFORMATION

RULE:
Inserts are used for attaching two or more parts, for structural strength, for decoration, and for conduction of electricity.

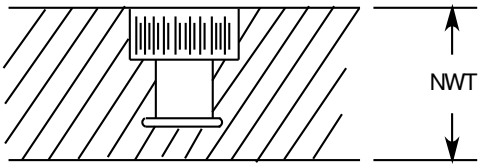
- Inserts fall into two groups: those molded-in or those installed after molding, for example, applied ultrasonically.
- Molded-in inserts are not recommended.

REASONING:
Inserts are preferred when disassembly is required and snap fits cannot be used. Ultrasonic inserts are recommended, as the current vendor base does not adequately support molded-in inserts.

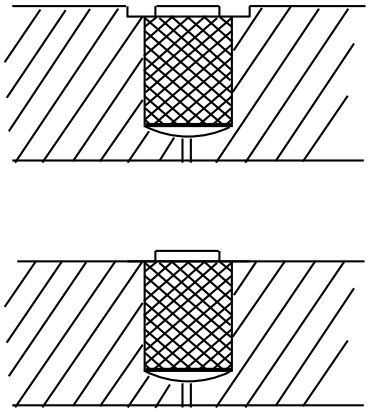
ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

Figure 2–22: Inserts



Ultrasonic Inserts



Molded–In Inserts

2.4.2.1 Ultrasonic Inserts

GUIDELINE

RULE:
The OD of the boss should be at least two times the insert outside diameter (OD). The inside diameter (ID) of the boss should be 0.4 to 0.5 mm (0.015 to 0.020 inch) smaller than the insert OD. The depth of the hole should be at least 1 mm (0.040 inch) longer than the insert.

When installed, the top of the insert should be flush or slightly below - 0.25 mm (0.010 inch) - the top surface of the boss.

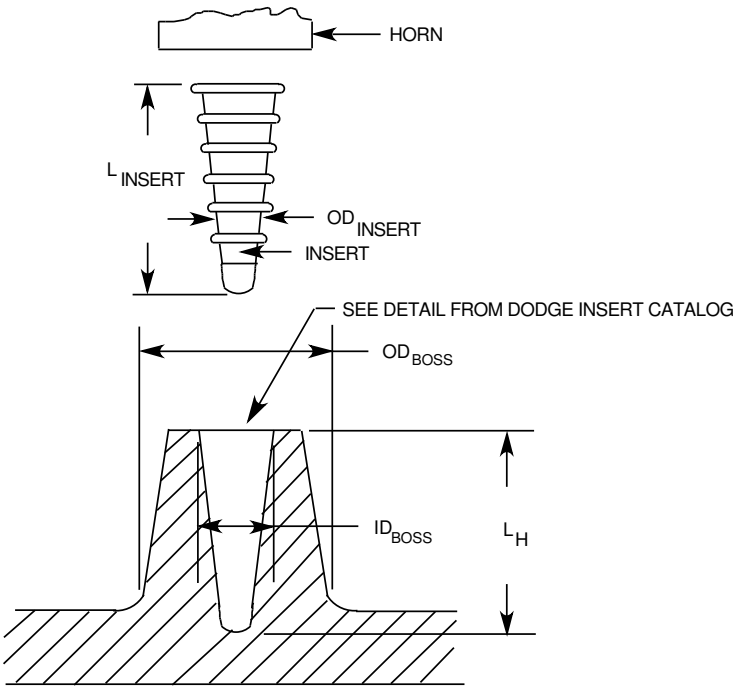
Refer to the insert Purchase Specification for specific dimensional requirements and the Hollow Boss Rule for design of bosses.

REASONING:
When applied correctly, inserts in thermoplastic materials are a very cost-effective base for threaded fasteners. By correctly matching the design of the boss to the insert dimensions, the insert can easily be ultrasonically installed and should not pull out in use or cause the boss to crack.

ALTERNATIVE:
Use another post-molded insert, such as press-in or self-threaded, or another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

Figure 2–23: Ultrasonic Inserts

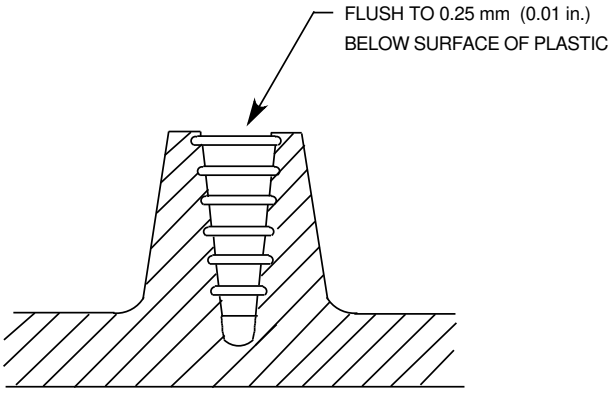


$OD_{BOSS} \geq 2 \times OD_{INSERT}$

$ID_{BOSS} = OD_{INSERT} - 0.4 - 0.5$ mm (0.015 – 0.020 in.)

$L_H > L_{INSERT} + 1$ mm (0.04 in.)

A: Insert Being Assembled



B: Assembled Insert

2.4.3 Threaded Fasteners

INFORMATION

RULE:

- Threaded fasteners are not recommended for most applications.
- Threaded fasteners are generally used for attaching two or more parts, for structural strength, and for conduction of electricity.
- Threaded fasteners used in the assembly of plastic parts are of three general types: machine screws and nuts, self-threading screws, and molded-in threads.
- Use bolt or screw heads with flat undersides. Use flat washers where necessary to increase load bearing area. Clamping of non-supported areas is not recommended.
- Indicate maximum allowable torque of 60% stripping torque.

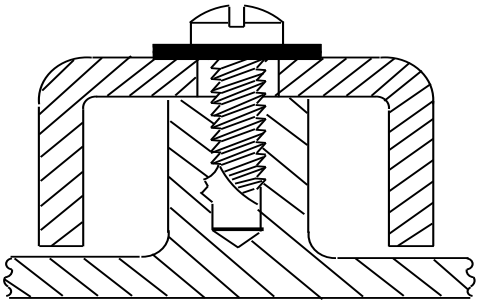
REASONING:
Threaded fasteners should be used in special applications where less part/labor intensive alternatives, such as snap fits, cannot be used. Care must be taken not to overstress the plastic during assembly.

Distribute the assembly force by use of bolt or screw heads with flat undersides and flat washers.

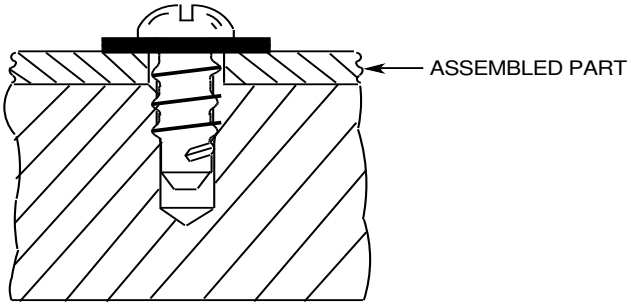
ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

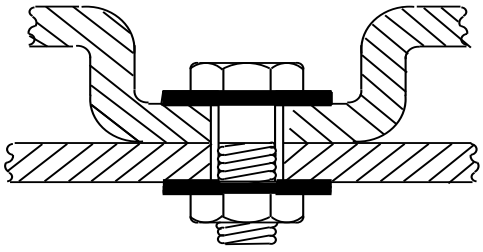
Figure 2–24: Threaded Fasteners



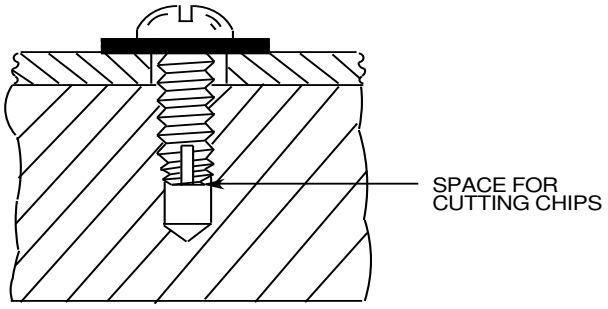
Machine Screw



Thread Forming Screw



Machine Screw With Nut



Thread–Cutting Screw

2.4.3.1 Machine Screws and Nuts

GUIDELINE

RULE:

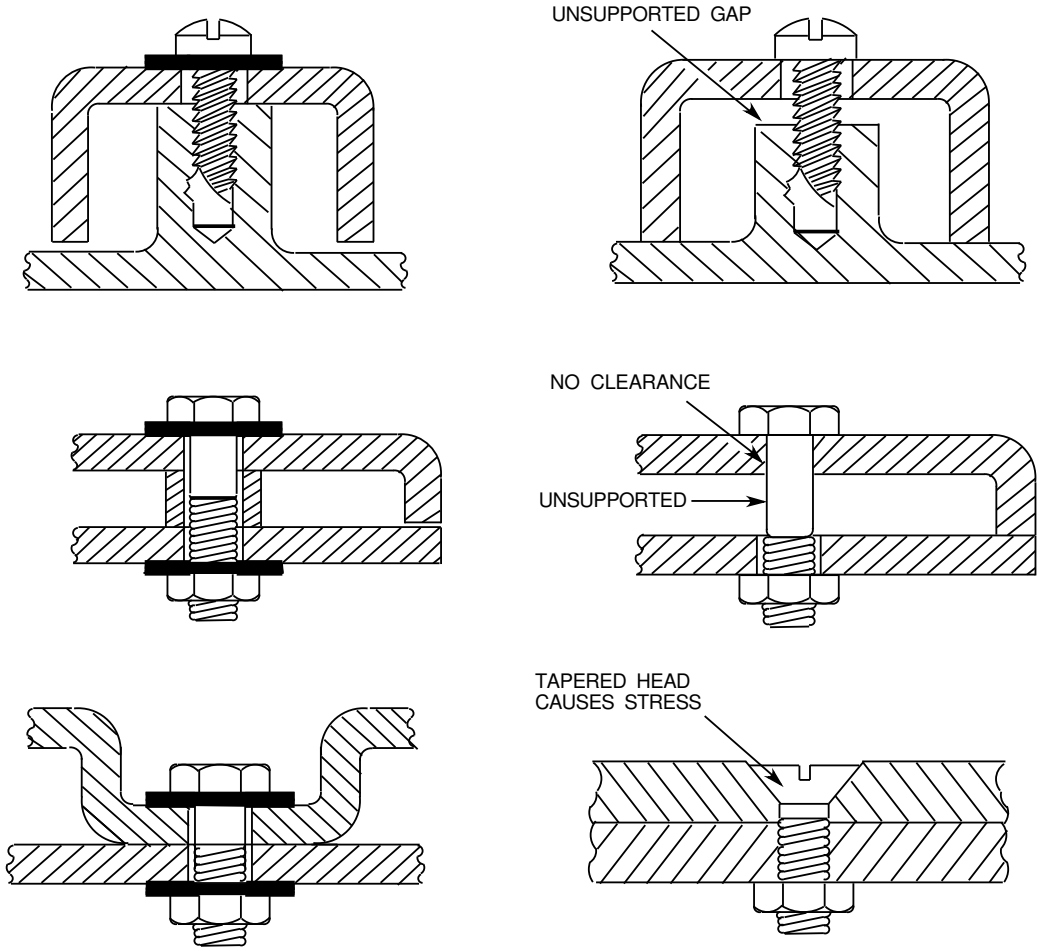
- Use bolt or screw heads with flat undersides. Use flat washers where necessary to increase load bearing area. Clamping of non-supported areas is not recommended.
- Provide adequate clearance between the body of the fastener and the part, dependent upon design requirements.

REASONING:
Screws and nuts should be used in applications where disassembly may be required and less part/labor intensive alternatives, such as snap fits, cannot be used. Care must be taken not to overstress the plastic. Distribute the assembly force by use of bolt or screw heads with flat undersides and flat washers.

ALTERNATIVE:
Use another fastening/joining method. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

Figure 2–25: Machine Screws and Nuts



2.4.3.2 Self-Threading Screws

GUIDELINE

RULE:

- Thread-forming type of self-threading screws are recommended for low modulus thermoplastics such as polyethylene, and plated applications.
- Thread-cutting type of self-threading screws are recommended for high modulus thermoplastics such as polycarbonate.
- Do not use self-threading screws where disassembly is required.
- Maximum allowable torque is 60% of stripping torque.

REASONING:
Self-threading screws are a fast and economical means of joining parts to plastics where no disassembly is expected and snap fits cannot be used.

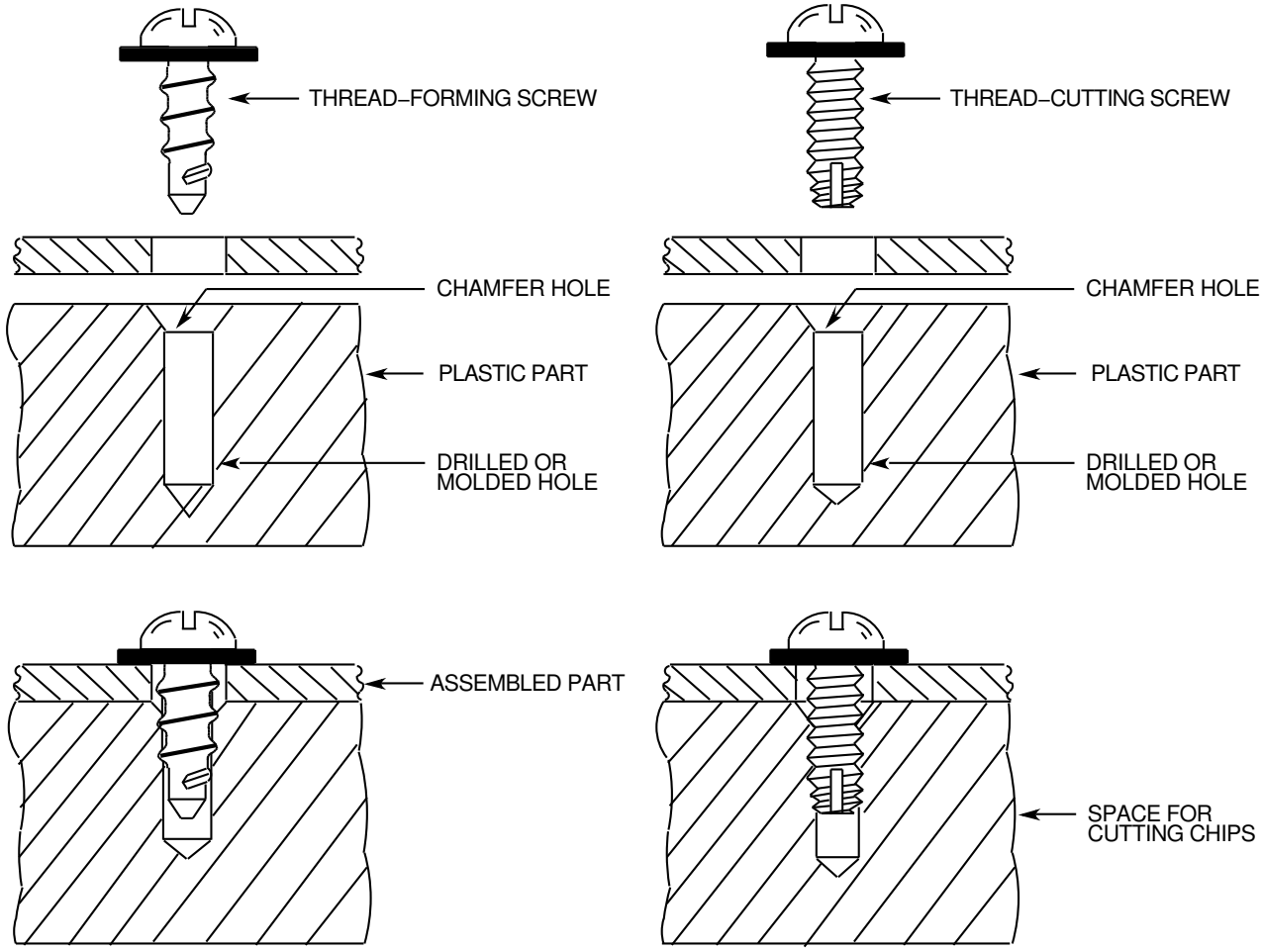
Care must be taken to match the screw type and shape to the plastic material to avoid overstressing the plastic during assembly.

Once a self-threading screw is removed, it is very difficult to rematch the threads.

ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

Figure 2–26: Self-Threading Screws



2.4.3.3 Molded-In Threads

GUIDELINE

RULE:
Molded-in threads are recommended for special applications only.

REASONING:
Molded-in threads are not recommended for general use because of mating parts problems, stress concentrations, and increased mold costs.

ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.4 Chemical Bonding

INFORMATION

RULE:

- There are two types of chemical bonding: adhesives and solvents.
- Chemical bonding is used in shear applications, when a sealed joint is required, and to avoid stress concentrations of mechanical parts.
- Generally, chemically bonded parts cannot be disassembled.
- Care must be taken in matching the chemical to the substrate material. Joint design is important for the resultant joint strength and ease of assembly.
- Because of environmental, safety, and stress concentration concerns, solvent based chemicals are not recommended.

REASONING:
Chemical bonding produces a permanent sealed joint that resists vibrations, stress concentrations, and crack propagation.

Environmental and safety concerns will affect the choice of chemicals.

ALTERNATIVE:
Use another fastening/joining method. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.4.1 Adhesive Bonding

GUIDELINE

RULE:

- Adhesive bonding is recommended in shear applications where a permanent, sealed joint is required and/or stress concentration of mechanical fasteners is to be avoided.
- It is important to match the adhesive to the substrate material. Joint design is important for the resultant joint strength and ease of assembly. See Figure 2–27.
- When selecting an adhesive, consider the production process, for example, plating, and the operating environment of the final part, that is, temperature, solvent cleaning, and so forth.

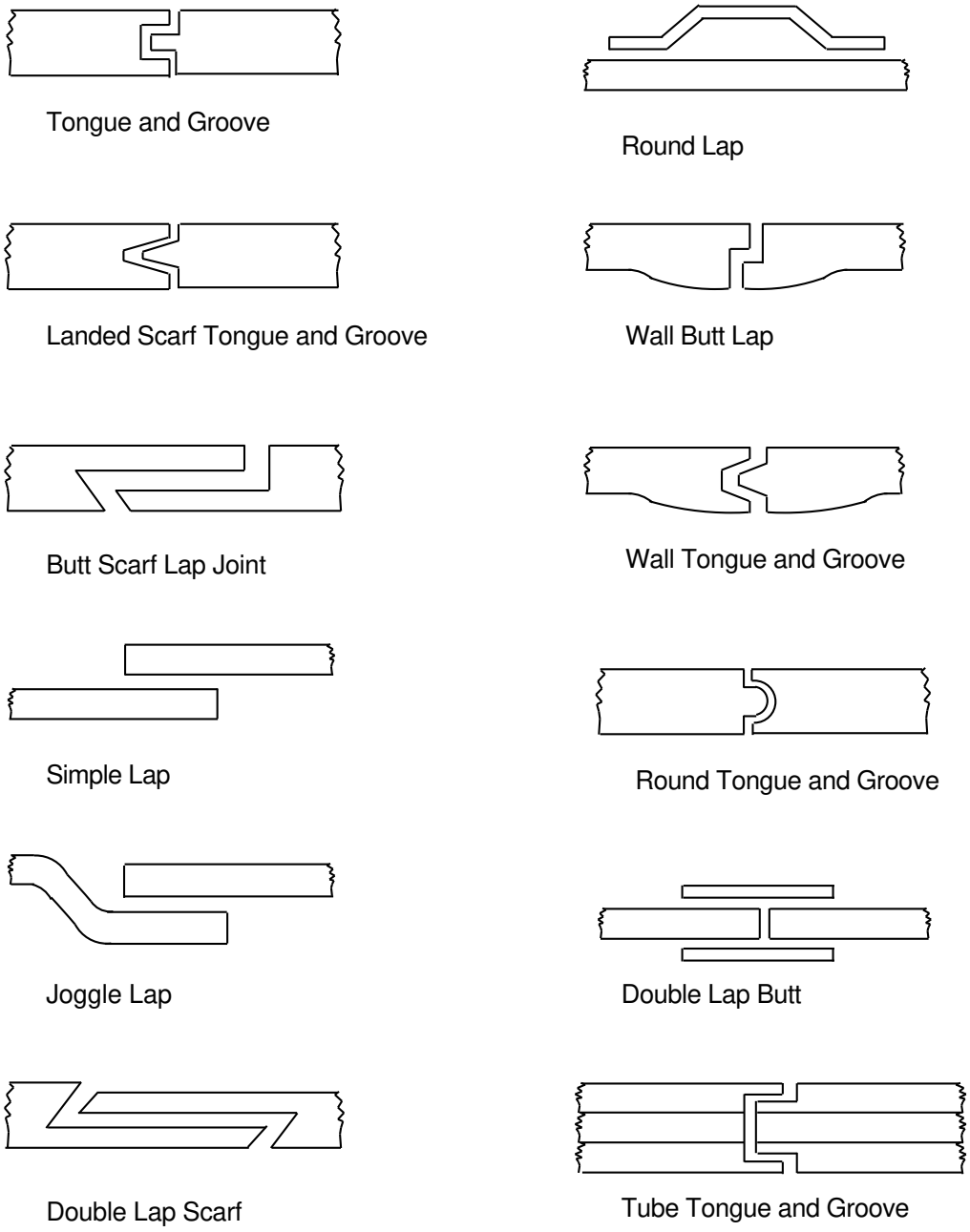
REASONING:
Adhesive bonding produces a permanent sealed joint that resists vibrations, stress concentrations, and crack propagation.

Environmental, safety, and process concerns will affect the choice of adhesive.

ALTERNATIVE:
Use another fastening/joining method. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

Figure 2–27: Adhesive Bonding



2.4.4.2 Solvent Bonding

GUIDELINE

RULE:
Solvent bonding is not recommended.

REASONING:
Solvent bonding is not recommended due to environmental, safety, and stress concentration concerns.

ALTERNATIVE:
Use another fastening/joining method. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.5 Frictional Welding

INFORMATION

RULE:

- There are three types of frictional welding: ultrasonic, spin, and vibration.
- Permanent joining of two or more plastic parts is achieved by frictional melting.
- The characteristics of the material, joint design, and process must be considered.

REASONING:
Cost-effective, rapid joining of two or more plastic parts can be done by frictional welding.

The materials involved affect the integrity of the joint.

ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.5.1 Ultrasonic Welding

GUIDELINE

RULE:

- Ultrasonic welding produces a permanent joint.
- Near-field welding, less than 6.4 mm (0.250 inch), from horn to weld, is preferred over far-field (greater than 6.4 mm).
- Care should be taken to insure that the material, joint design, and process are compatible. See Figure 2–28.
- Ultrasonic welding is not recommended when a sealed joint is required.

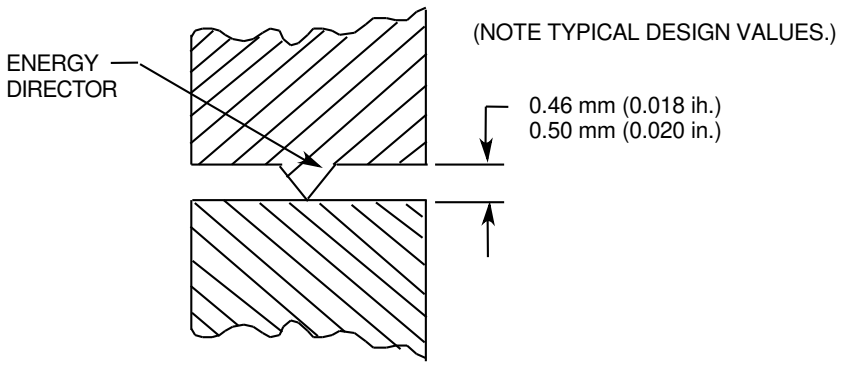
REASONING:
Ultrasonic welding produces a permanent joint between two or more plastic parts without the use of hardware or adhesives. They cannot be disassembled without destroying the parts.

The materials involved affect the joint.

ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

Figure 2–28: Ultrasonic Welding



Butt joint with energy director for ultrasonic welding

2.4.5.2 Spin Welding

GUIDELINE

RULE:
Spin welding is not recommended.

REASONING:
Spin welding is not recommended due to the limited vendor base and the need for circular parts.

ALTERNATIVE:
Use another fastening/joining method. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.5.3 Vibration Welding

GUIDELINE

RULE:
Vibration welding is not recommended.

REASONING:
Vibration welding is not recommended due to the limited vendor base.

ALTERNATIVE:
Use another fastening/joining method. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.6 Applied-Heat Welding

INFORMATION

RULE:
Permanent joining of two or more parts is achieved by applied-heat welding.

- Types of applied-heat welding used for plastic assembly are heat-staking, hot-platen, induction, and bead.
- Of the above, only heat staking is recommended.

REASONING:
Cost-effective, rapid joining of two or more parts can be done by heat staking.

The materials involved affect the integrity of the joint.

Hot-platen and induction welding are not recommended due to the limited vendor base.

ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.6.1 Hot-Platen Welding

GUIDELINE

RULE:
Hot-platen welding is not recommended.

REASONING:
Hot-platen welding is not recommended due to the limited applications and vendor base.

ALTERNATIVE:
Use another fastening/joining method. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.6.2 Induction Welding

GUIDELINE

RULE:
Induction welding is not recommended.

REASONING:
Induction welding is not recommended due to the limited applications and vendor base.

ALTERNATIVE:
Use another fastening/joining method. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.6.3 Bead Welding

GUIDELINE

RULE:
Bead welding is not recommended.

REASONING:
Bead welding is not recommended due to the limited applications and vendor base.

ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.6.4 Heat Staking

GUIDELINE

RULE:

- Heat staking is used to produce a permanent joint.
- Care should be taken to insure that the material, joint design, and process are compatible. See Figure 2–29.
- Heat staking is not recommended for a sealed joint or for crystalline material.

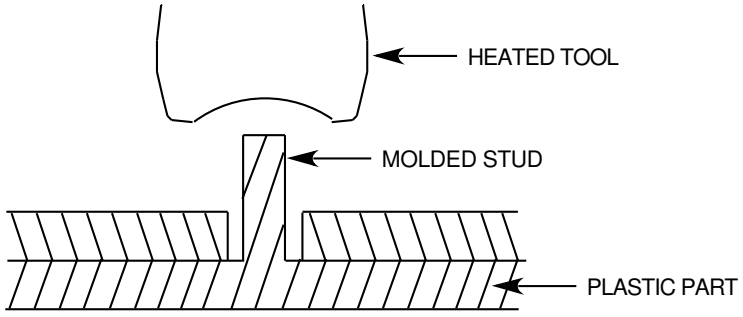
REASONING:
Heat staking produces a permanent joint between two or more plastic parts without the use of hardware or adhesives. They cannot be disassembled without destroying the parts. The process is capable of forming multiple joints at the same time.

The materials involved affect the joint. Amorphous materials are easier to heat stake than crystalline materials.

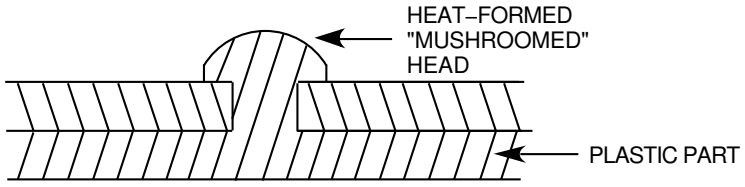
ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

Figure 2–29: Heat Staking



BEFORE STAKING



AFTER STAKING

2.4.7 Mechanical - Without Fasteners

INFORMATION

RULE:
There are two types of mechanical joining without fasteners, snap fit and press fit.

REASONING:
Features can be molded into plastic parts that allow joining without additional hardware. These features can result in permanent joints (press fit) or removable joints (snap fit).

ALTERNATIVE:
Use another fastening/joining method. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.7.1 Snap Fit

INFORMATION

RULE:
Snap fits use elastic displacement for fastening and joining. Snaps and tabs and other flexible features can be used to join two or more parts together. See Figure 2–30.

REASONING:
Molded-in snap fits provide a low-cost means for rapid assembly and disassembly of two or more parts.

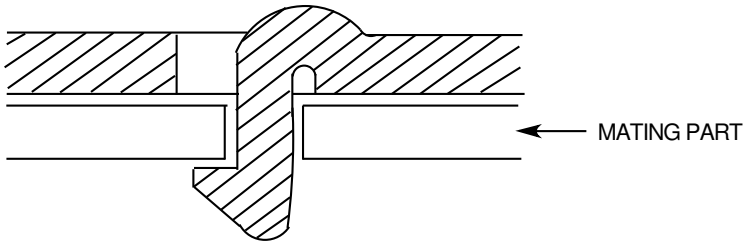
NOTE

Snap and tab features can be designed to inhibit disassembly, if desired.

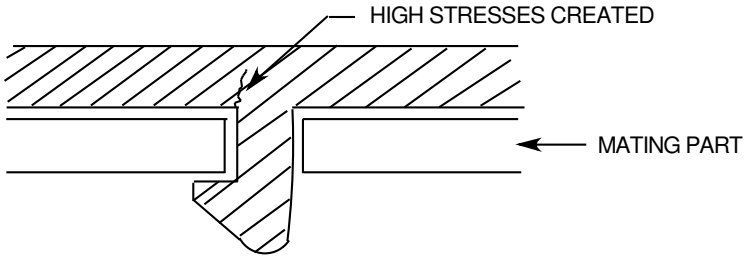
ALTERNATIVE:
Assembly requirements could be met with mechanical fasteners or other joining methods such as adhesives, heat staking, and so forth.

ALTERNATIVE IMPACT:
The above alternatives may increase material and labor costs and decrease quality.

Figure 2–30: Snap Fit



A: Recommended



B: Not Recommended

2.4.7.1.1 Design of Snaps

GUIDELINE

RULE:
Proper snap design is dependent upon the flexural characteristics of the material and the cantilever design of the snap. Analysis must be performed on all the snap features. See Figure 2–31.

NOTE

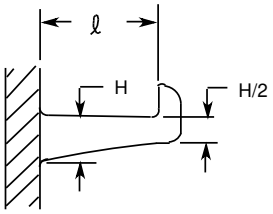
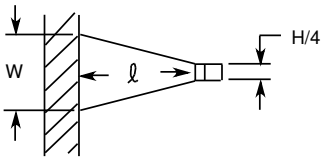
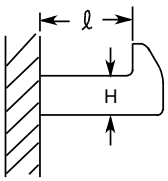
Contact Producibility Engineer for material modulus values.

REASONING:
Snap performance and life are dependent upon the material characteristics and design parameters. Incorrect design can lead to part failure, assembly problems, and/or expensive tooling rework.

ALTERNATIVE:
Assembly requirements could be met with mechanical fasteners or other joining methods such as adhesives, heat staking, and so forth.

ALTERNATIVE IMPACT:
The above alternatives may increase material and labor costs, decrease quality and inhibit disassembly.

Figure 2–31: Design of Snaps

Cantilever Snap Shape	Rectangular Cross Section	Trapezoidal Cross Section
Taper (preferred)  (Side View: W = Constant)	DC = 1.09	DC = 1.64 $\frac{W+X}{2W+X}$
 (Top View: H = Constant)	DC = 0.86	DC = 1.28 $\frac{W+X}{2W+X}$
 (Side View: W = Constant, H = Constant)	DC = 0.67	DC = $\frac{W+X}{2W+X}$
Section Modulus for all Snap Shapes	SM = $\frac{WH^2}{6}$	SM = $\frac{H^2}{12} + \frac{W^2 + 2WX + X^2}{2W + X}$

Equations:

$$\text{Load} = sm \circ \left(\frac{E\epsilon}{\ell}\right) \; ; \; \text{Deflection} = DC \; \frac{\epsilon \ell^2}{H}$$

Symbols:

SM = Section Modulus
DC = Deflection Coefficent
E = Flexural Modulus
ϵ = Strain at Root of Snap
ℓ = Effective Length of Cantilever Snap

Note: Load applied and deflection measured at distance "ℓ" from root of snap.

2.4.7.2 Press Fit

GUIDELINE

RULE:

- A mechanical press fit is a permanent assembly of two parts using interference features.
- Use only for low load, shear applications. Press fits should be avoided and are not recommended for harsh environments, that is, thermal cycling.
- Because material displacement generates the retention force, do not exceed the recommended dynamic strain limit of the material. Avoid locating a weld line on the inserted area.
- The inserted part can be smooth or knurled. Avoid inserting a smooth part into a blind hole.
- Care must be taken to ensure compatibility between mating parts, for example, thermal expansion.

REASONING:
Press fits can be an economical means of permanently joining two parts without additional parts or adhesives. Tooling costs can be lower with improved tool life.

Permanent stresses are set up in the material. Thus, the dynamic strain limits of the materials must be considered. Knit/weld lines are high stress zones and must be avoided in the inserted area.

Harsh environments should be avoided. High stressed parts are more vulnerable to chemical and thermal attack. Thermal cycling can result in loss of retention force.

The application should determine the detail design. Knurled features could increase the stress. A smooth part inserted into a blind hole can increase stress by the entrapped gasses.

ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

2.4.7.3 Special Applications

INFORMATION

RULE:
There are many special fastening devices on the market today. Some examples are: hinges, spring snaps, hook and loop, press-on clips, and barbed fasteners.

REASONING:
Special fastening devices can be very effective if utilized properly. Refer to the Producibility Engineer for specific design and process impacts.

ALTERNATIVE:
Use another fastening/joining method, with snap fits recommended.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements.

2.5 SPECIAL FEATURES

This section contains rules specific to the design of special features. See Figure 2-32.

2.5.1 Molded-In Characters

GUIDELINE

RULE:

- Molded-in characters are a permanent means of adding text to a plastic part. The characters can be raised or recessed.
- Raised characters are preferred over recessed.
- Character draft angle should be 5 degrees.

REASONING:
Molded-in characters are a cost-effective means of adding text to plastic parts. Non-textured characters are preferred.

Mold tool life of the characters is reduced with recessed characters.

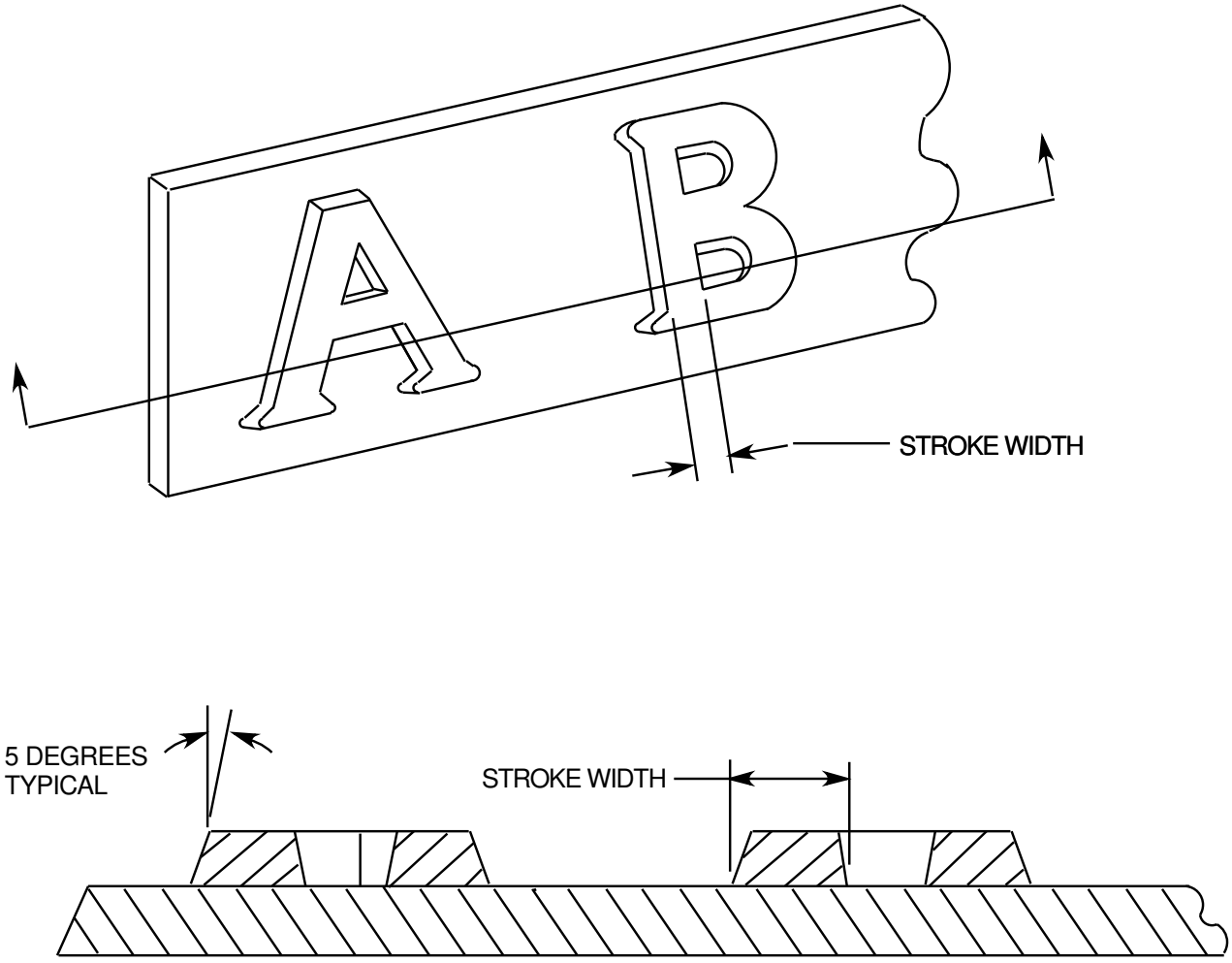
A 5 degree draft angle is recommended to maintain character definition.

Consider using inserts if the text is subject to change.

ALTERNATIVE:
Use labels, silk screening, pad printing, or hot stamp.

ALTERNATIVE IMPACT:
Secondary operations increase cost and reduce quality. Refer to the Producibility Engineer.

Figure 2–32: Special Features



Enlargement of cross section

2.5.2 Surface Finish

GUIDELINE

RULE:

- Depending upon the Design requirements, the surface finish/texture of the finished part can be produced either by the mold or a post-finishing process.
- For molded-in finish/texture, refer to *DEC STD 092 Finish and Color Standard - Introduction and General Requirements*. Include the SPI/SPE and/or the Mold Tech Number on the drawing. Indicate the areas to be textured.
- For molded-in texture, increase the draft angle 1 degree for each 0.025 mm (0.001 inch) of texture depth. (Plastic Design Rule #2.3).
- If the part is to be post-finished/textured, make allowance for the thickness of the finish/texture.

REASONING:
Molded-in texture/finish is usually more cost effective than painting and other post-molding processes. The final finish/texture is more uniform using the molded-in process.

Paint fill usually requires 0.04 mm (0.0015 inch) minimum thickness allowance.

Refer to the Plastic Finishes Rules.

ALTERNATIVE:
Use another finishing/texturing method such as painting. Refer to the Producibility Engineer for specific design recommendations.

ALTERNATIVE IMPACT:
Positive or negative impacts of the alternatives would have to be evaluated based upon specific design requirements. Refer to the Producibility Engineer.

APPENDIX A REFERENCED DOCUMENTS

A.1 EL-Class Digital Documents

EL-Class Number	Document Title
EL-00092-00	*DEC STD 092-0 Finish and Color Standard - Introduction and General Requirements*
EL-EN729-01	*Finishing Rules Handbook for Plastics*

Use VTX SMC to order copies of EL-class documents from Standards and Methods Control. Send distribution questions to JOKUR::SMC or call DTN: 234-4423.

EL-EN729-01 this document is currently in process.

APPENDIX B RELATED DOCUMENTS

B.1 EL-Class Digital Documents

EL-Class Number	Document Title
EL-00076-00	*DEC STD 076-0 Plastics Selection and Identification*
EL-00119-00	*DEC STD 119-0 Digital Product Safety - Introduction and General Requirements*

Use VTX SMC to order copies of EL-class documents from Standards and Methods Control. Send distribution questions to JOKUR::SMC or call DTN: 234-4423.

GLOSSARY

adhesive: A material which bonds to the surface of (typically two) other materials to attach those surfaces.

amorphous: Molecules which have no regular shape or structure. Without tight intermolecular fit or bonds. See *crystalline*.

annealing: Process of heating a material just below its heat distortion point to relieve stresses.

ANSI: American National Standards Institute.

ASME: American Society of Mechanical Engineers.

ASTM: American Society for Testing and Materials.

blind hole: A small, typically circular depression in the nominal wall that does not perforate through both sides of the wall.

boss: A projection, typically round in shape, designed to assist in assembly with another part.

built-in stresses: Stresses left in a part when no external loading is present. Built-in stresses are created during the manufacturing process as molten plastic freezes while being stressed. Also called *residual stress*.

catalyst: A chemical that agitates, accelerates, or causes a chemical reaction but does not itself become part of the new compound. An example would be the peroxides used to cure polyesters.

cavity: The depression or female portion of the mold that forms the external shape of the part being molded.

chemical bonding: Joining of two or more parts by altering the molecular structure of the surfaces of the joined parts.

cold flow: See *creep*.

copolymerization: A material made by combining two different monomer systems.

core: 1. *core* of the mold: The projection or male portion of the mold that forms the internal shape of the part being molded. 2. *core* pin: A pin or protrusion that produces holes or depressions on the piece part.

coring: (designing) The process of hollowing out a thick section resulting in thicknesses not exceeding the nominal wall thickness.

crazing: Development of fine cracks on a plastic surface.

creep: Deformation or change of dimensions of a material under a constant load over a period of time, after the initial deformation when the load is first applied. This occurrence at room temperature is called *cold flow*.

crystalline: (crystalline polymers) Having an identically constituted molecular structure or tight, parallel molecular chains which fit together in a regular way.

depressions: Features of a part which extend into the nominal wall.

draft: The angle or taper required on a molded part to facilitate the removal of the part from the mold.

ejector pin: A mechanical part of an injection mold which is used to push the solidified part out of the mold. Ejector pins can also be used for mold venting, and leave a blemish on the surface of the part.

elastic limit: The extent to which a material can be stretched or deformed before taking a permanent set. Permanent set occurs when the stressed material does not recover its original dimensions.

EMI: Electromagnetic interference.

fastener: Hardware that is soully used to attach two or more components together.

fillers: Materials added to the basic plastic compound to obtain particular electrical, chemical, processing, or mechanical properties.

flash: Excess material found along the parting line of a molded part.

gate: The part of the mold where plastic is injected into the party cavity.

glue line: The adhesive layer between two adherends.

gusset: A special form of rib that forms an angle between the nominal wall and the side wall or another projection.

heat deflection temperature (HDT): The temperature at which a standard test bar deflects 0.25 mm (0.010 in.) under a stated load of either 66 or 264 Psi (0.45 or 1.82 MPa). (ASTM #D648.)

hygroscopic: The quality of being able to absorb and retain moisture.

injection molding: A process in which, generally, a thermoplastic material is heated to a molten state in a heating cylinder and then forced hydraulically into a cooled mold to produce a desired shape.

insert: Fastening hardware that is permanently set into a part either during molding or in a post-molding process.

knit line: A weld line (see definition) where the wave fronts of two plastic flows meet at less than a 90 degree angle. Knit lines have a higher structural strength than weld lines, where wave fronts meet head-on.

louvers: An array of depressions that extend through the nominal wall typically for airflow purposes.

modulus: The ratio of stress to strain in a material when it is elastically distorted. A measure of stiffness or resistance to bending. All computation for modulus is made within the elastic limit. (ASTM D790.) Typical units are megaPascals (MPa) or pounds per square inch (psi).

mold: 1. process: To shape or form an article. 2. manufacturing tooling: An entire mechanism required to form thermoplastic, thermoset, and other materials, that is, cavities, cores, plungers, frame blocks/holders, and extractors.

mold-cooling: The stage of the injection-molding manufacturing cycle after the mold has been filled and pressurized and before the part is ejected from the mold. Mold-cooling time is the driving factor in manufacturing cycle time, and usually increases with the thickest section of the part.

mold-filling: The stage of the injection-molding manufacturing cycle when molten thermoplastic material is rapidly injected into the mold at high presure.

molded-in: Features that are built into a component during the molding process.

monomer: An organic molecule which can be chemically bonded as a unit of a polymer.

nominal wall: The base wall of an injection molded part normal to the closing direction of the mold.

nominal wall thickness (NWT): The average (that is, statistical mode) thickness of the nominal wall of a part.

oblique: At an angle other than 0, 90, or 180 degrees.

parison: The thermoplastic tubular extrusion that is inflated within a mold in the blow-molding process.

parting line: The line around a molded part, typically visible, where the two halves of the mold meet when closed. Venting can also occur along the parting line.

periphery: The outer edges of an object.

permanent set: See *elastic limit*.

polymer: A high molecular weight material composed of repeated links of monomeric units.

press fit: A join between two parts which closely fit together with limited interference. To join the parts, one part is pressed into the other causing each to compress to some degree. This leaves the parts permanently deformed inducing normal forces between the fit surfaces of the parts.

projections: Features that extend above the nominal wall.

residual stress: See *built-in stresses*.

RFI: Radio frequency interference.

rib: A projection, typically long and thin with one long edge free, that is used usually for stiffening, particularly wall sections.

rivet: Fastening hardware in which one end is permanently deformed in a way that interferes with its removal.

shrink factor: The ratio of dimensional change that takes place during the cooling of a molded plastic part. Other contributors to the shrink factor are material, part configuration, wall thickness, gating/runner systems, molding temperatures, fillers, and shrink fixtures.

shrink fixture: A form on which the hot molded parts are placed so that they do not shrink or deform during the cool down cycle.

shrinkage: The decrease in size of a molded article caused by the cooling of the material.

side wall: A wall projecting from the nominal wall of a part.

sink mark: A shallow depression on the surface of a molded part caused by internal shrinkage of the material after the gate seals. Sink marks often occur in areas of the part that do not maintain the nominal wall thickness.

slide: A portion of a mold that is made to move at an angle to the normal movement of the molding machine, to allow for the extraction of undercuts, recesses, holes, or other features that prohibit the removal of the part from the mold.

snap fit: A design feature which is used to join one part to another by creating a mechanical interference between the parts in which the interfering surfaces can be deflected out of the way for assembly or disassembly.

solvent bonding: The bonding together of two thermoplastic surfaces by the application of a chemical solvent that partially dissolves the mating surfaces, then evaporates allowing the parts to resolidify as one part.

SPE: Society of Plastics Engineers.

SPI: Society of the Plastics Industry.

staking: A process similar to riveting where the "staked" component is inserted through another (for example, a solid boss through a hole), and the inserted end of the staked component is permanently deformed in a way that interferes with its removal.

strain: The dimensional change of a material under stress, expressed in millimeters per millimeter (mm/mm) or inches per inch (in/in).

stress: The pressure applied to a material, often expressed in pounds/square inch (Psi) or megapascals (MPa).

texture, surface: Regular shaping of an otherwise smooth surface whose details are too small to be visually apparent, but provide an overall visual difference.

thermal conductivity: Ability of a material to conduct heat; physical constant for the quantity of heat which passes through unit cube of a substance in a unit of time when the difference in temperature of the two faces is 1 degree Centigrade. (ASTM #C177.)

thermoplastic: A polymer that can be repeatedly softened by heating and repeatedly hardened by cooling.

thermoset: A polymeric resin that changes into a relatively infusible material through the formation of cross-linked, covalently-bonded molecules. This change is irreversible.

thixotropic: A term that describes a filled resin that has little or no movement when applied to a vertical plane. Powdered silica or other fillers are usually used as thickening agents.

thread-cutting screw: A threaded fastener that makes its threads in the base material by mechanically cutting threads into the base material.

thread-forming screw: A threaded fastener that makes its threads in the base material through deformation.

transition: A region of a part where change occurs, especially surface curvature and/or thickness changes.

UL: Underwriters Laboratories.

UL 94: Underwriters Laboratories Flammability Evaluation Test.

undercut: A recess or depression in the molded part, located in such a position that it impedes or makes impossible the ejection of the part during the normal opening of the mold.

venting: The process of letting air escape from inside of a mold during mold filling.

voids: Small volumes inside an injection-molded part without plastic. This is caused by the same mechanism as sink marks.

warpage: Changes in the shape of an injection-molded part after ejection, due to variations in shrinkage.

weld line: When an injection mold is filled, often two wave fronts of the molten plastic meet. The line where these two fronts meet is called a *weld line*; it is characterized as being a structurally weak spot in the part and also blemishes the appearance of the part. See also *knit line*.

welding: The process of permanently joining two or more parts by melting the surfaces of the parts so that they harden as a single part.

welding, applied heat: Direct heat is used to melt the surfaces of the parts to be joined.

welding, frictional: Heat to melt the surfaces of the parts to be joined is generated by dissipation of stresses induced by external or internal movement of material.

witness line: A small and typically unwanted mark on a part's surface which indicates where two parts of a mold meet (for example, around a core pin).

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